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PHASE I AND II FINAL MATERIAL REPORT ON UNIDIRECTIONAL LIGHTWEIGHT ENEFGY ABSORBING NET COUCH RESTRAINT SYSTEM FOR USE IN APOLLO OR FOLLOW-ON PROJECTS

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WEBER AIRCRAFT

DIVISION OF WALTER KIDDE & COMPANY INC.

BURBANK, CALIFORNIA

ENGINEERING REPORT

DR 5895

ON

PHASE I & II FINAL MATERIAL REPORT
ON
UNIDIRECTIONAL LIGHTWEIGHT ENERGY ABSORBING NET COUCH
RESTRAINT SYSTEM FOR USE IN APOLLO OR FOLLOW-ON PROJECTS

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

Contract No. NAS 9-3497

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1.0 PURPOSE

During the initial phases of the Apollo Couch Development Program at Weber Aircraft, effort was concentrated on the development of a fabric body support concept which would satisfy the requirements of a couch system for the Apollo or follow-on spacecraft.

This final Materials Test Report documents the results of the investigation by Weber Aircraft to develop satisfactory materials for the Apollo energy absorbing net couch. The report is issued to satisfy the requirements of Item IX in the NASA-MSC Contract No. NAS 9-3497 which stipulates that Weber Aircraft shall summarize the results from tests, experiments, developments, studies and other efforts relating to materials and their processing for use in fulfilling the technical requirements of the contract.

A complete description of the development work accomplished during this program is presented in Reference 1.

2.0 SUMMARY

Three different body support concepts were fabricated. Each was statically and dynamically tested on a boilerplate couch structure and evaluated on its ability to satisfy the requirements of the program. The scope of these requirements included couch occupant comfort and weight distribution, articulation capability and system response characteristics to spacecraft launch, and landing impact load conditions.

In the course of developing these systems, tests were performed on selected synthetic fibers which appeared to posses the required high impact plastic hysteretic characteristics. The materials selected for test were partially drawn Nylon yarn, fully drawn Nylon yarns, formic acid and treated Nylon yarns, and heat shrunk Dacron yarns.

This book summarizes the data collected during the experiments performed on various material samples and indicates the results of each phase of the tests performed.

These tests indicated Nylon 6 yarns, in a 13.5/12.5 3 ply cord construction, most nearly satisfied the requirements of the program.

3.0 SYNTHETIC FIBER YARN TESTS

3.1 Partially Drawn Nylon Yarns

Samples of duPont Type N-13 undrawn nylon yarn were subjected to varying degrees of drawing, using both hot and cold drawing techniques. The samples were then subjected to both static and dynamic tensile testing.

A summary of the tensile test data for these materials is tabulated in Table 1.

TABLE 1

TENSILE TEST DATA OF N-13 NYLON YARN
(965 denier, 34 filaments)

	Static		Dynamic	
	Instron at 20"/min 2 inch, gage length		30'/sec 3 inch gage length	
	Breaking Load gms	Elongation %	Breaking Load gms	Elongation %
Control (Undrawn)	998	466	620	280
Drawn 50% at 70°F	1098	366	640	280
at 370°F	1140	317	-	-
Drawn 100% at 70°F	1223	206	745	220
at 365°F	1083	154	643	180
Drawn 200% at 70°F	1304	81	1294	13
at 380°F	1159	56	-	-
Drawn 400% at 70°F	1524	35	953	16
at 370°F	1588	18	-	-

Nylon 6 was known to exhibit the energy absorbing characteristics required. Therefore, a controlled series of tests were run to establish the qualitative effect of atmospheric moisture content on the stress-strain relationship of the yarn. This material was supplied by Allied Chemical Company, coded BWS 13. It is a 750 denier, 16 filament, zero twist yarn. The results are plotted on Figure 1. Another test series, establishing the effect of temperature, is plotted on Figure 2.

3.2 Fully Drawn Nylon Yarns

Fully drawn 840 denier, 140 filament with 1/2 twist, type 300 duPont Nylon was required for application in one of the systems tested. Its stress-strain characteristics are shown on Figure 3.

3.3 Formic Acid Treated Nylon Yarns

Drawn nylon yarns shrunk in formic acid solution exhibit high elongation properties. Based on past work in this area an acid concentration (59%) was used throughout. Varying temperature and reaction time a treatment formula which would provide a shrunk nylon with the required properties was determined. The results are shown in Figure 4 and Table 2.

3.1 Partially Drawn Nylon Yarns - Cont.

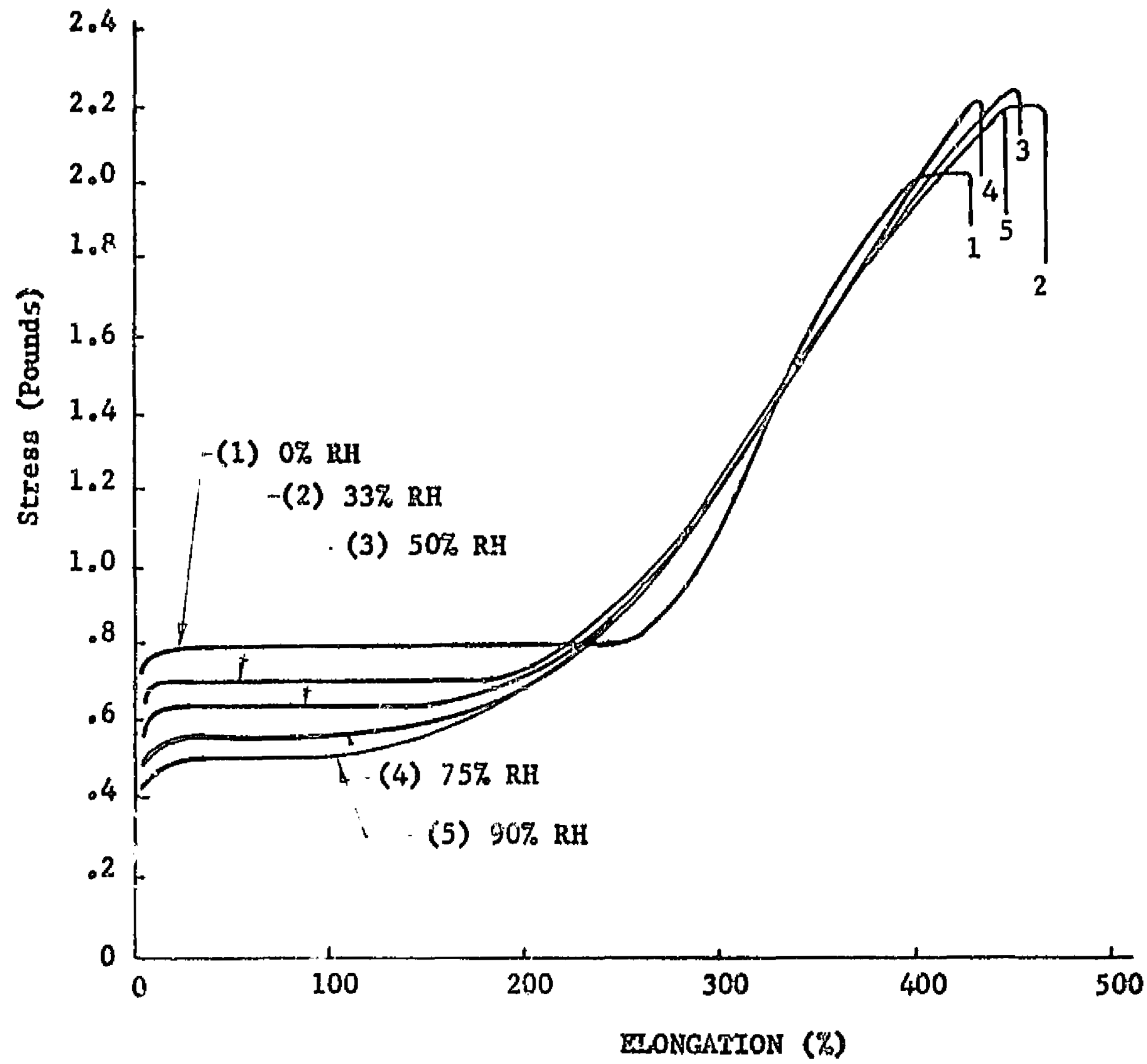
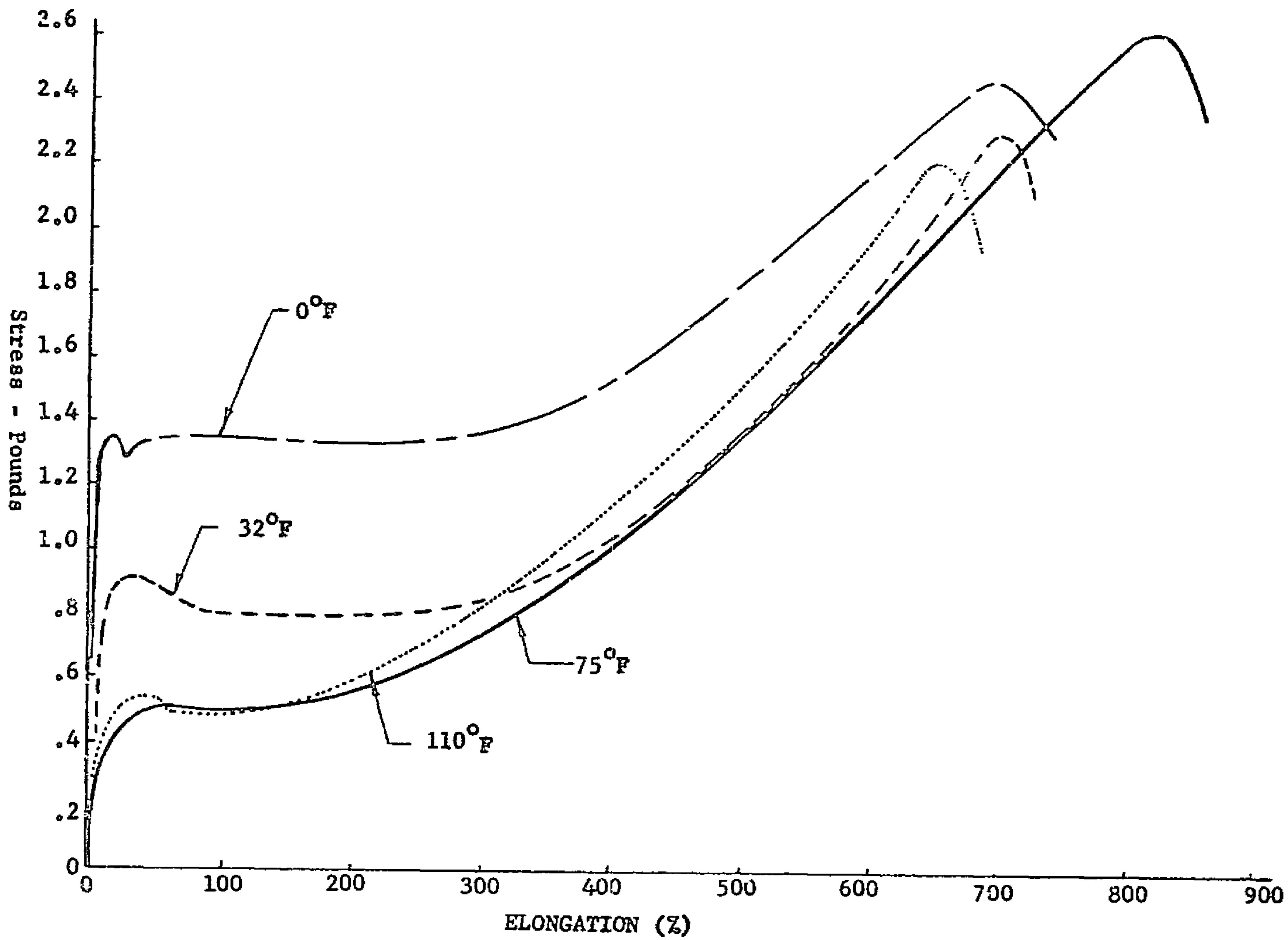


FIGURE 1
EFFECT OF MOISTURE ON STRESS-STRAIN OF 750 DENIER UNDRAWN NYLON 6 YARN

3.1 Partially Drawn Nylon Yarns - Cont.



EFFECT OF TEMPERATURE ON STRESS STRAIN OF
750 DENIER UNDRAWN NYLON 6 YARN

FIGURE 2

3.2 Fully Drawn Nylon Yarns - Cont.

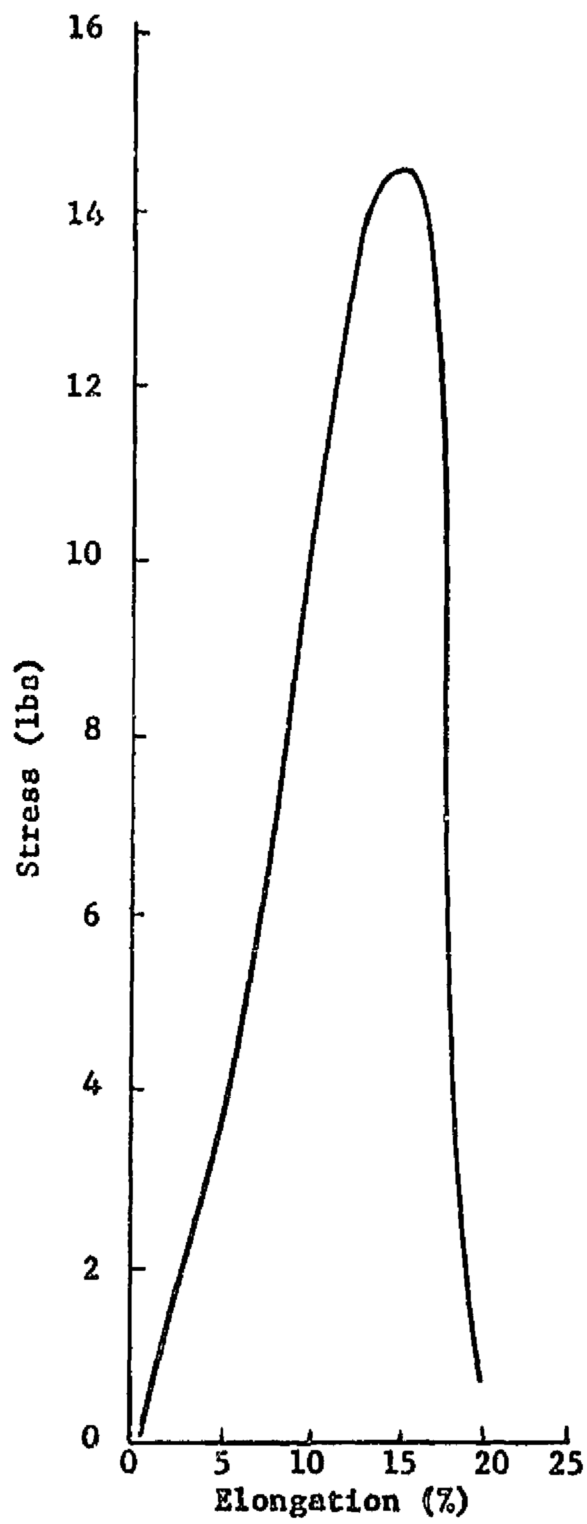


FIGURE 3
STRESS STRAIN OF
840 DENIER NYLON 300
STABILIZING CORD

3.3 Formic Acid Treated Nylon Yarns - Cont.

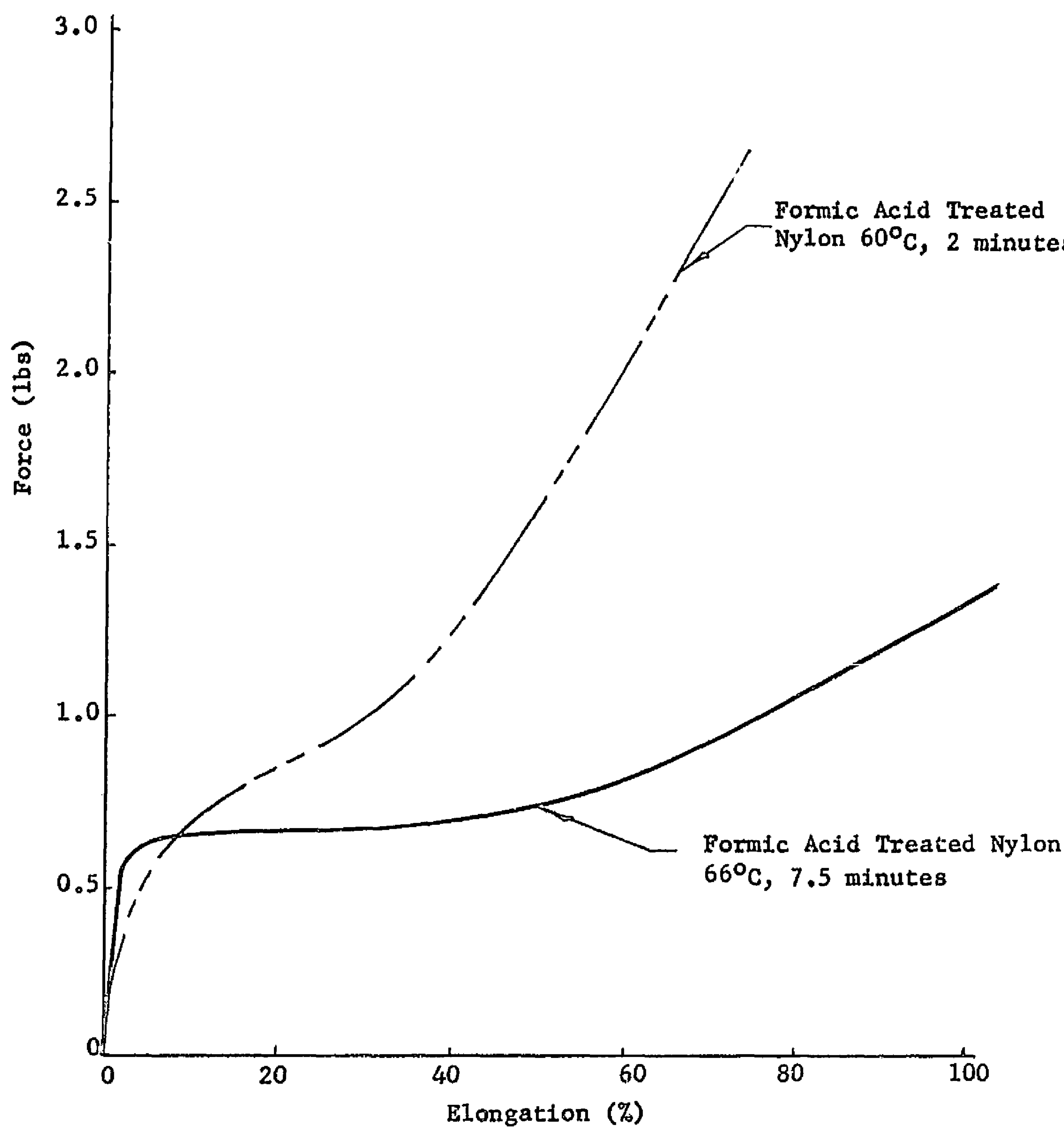


FIGURE 4

LOAD ELONGATION CURVES FOR FORMIC ACID TREATED NYLON YARNS TESTED AT 30 FEET PER SECOND

3.3 Formic Acid Treated Nylon Yarns - Cont.

TABLE 2

TENSILE TEST DATA OF FORMIC ACID TREATED NYLON YARNS

	Static		Dynamic	
	Instron at 5"/min 5 inch gage length		30'/sec 3 inch gage length	
	Breaking Load gms	Elongation, %	Breaking Load gms	Elongation %
Control (Type 300 Nylon 55)	1669	18.9	1700	13.3
Treated 59% HCOOH at 66°C for 15 min	1397	45.4	1580	40
Treated 59% HCOOH at 66°C for 7 1/2 min	1050	112.4	508	101
Treated 59% HCOOH at 50°C for 2 min	1373	64	1135	52
Treated 59% HCOOH at 60°C for 2 min	1202	79	1135	72

3.4 Heat Shrunk Dacron

Certain types of Dacron yarns when exposed to elevated temperatures shrink considerably, resulting in materials which posses energy-absorbing capability through higher elongations to break. Samples of Type 52 (110 denier) Dacron yarn, and type 5100 (220 denier) yarn were subjected to thermal treatments, and then tested both statically and dynamically to determine strength and elongation properties.

3.4 Heat Shrunk Dacron - Cont.

Results of these tests are summarized in Table 3. The stress-strain curve for Type 5100 treated at 400°F for 1 minute is shown in Figure 5.

TABLE 3

TENSILE TEST DATA OF DACRON YARNS

	Static: Instron at 5"/min, 5 inch gage length		Dynamic: 30'/sec, 3 inch gage length	
	Breaking Load gms	Elongation %	Breaking Load gms	Elongation %
Type 52 (1100 denier)				
Treated at 350°F for 2 min	7850	33	5992	26
Treated at 400°F for 1 min	8172	50	5600	33
Type 5100 (220 denier)				
Treated at 350°F for 2 min	1362	36	1378	25
Treated at 400°F for 1 min	1285	47	1200	41

3.4 Heat Shrunk Dacron - Cont.

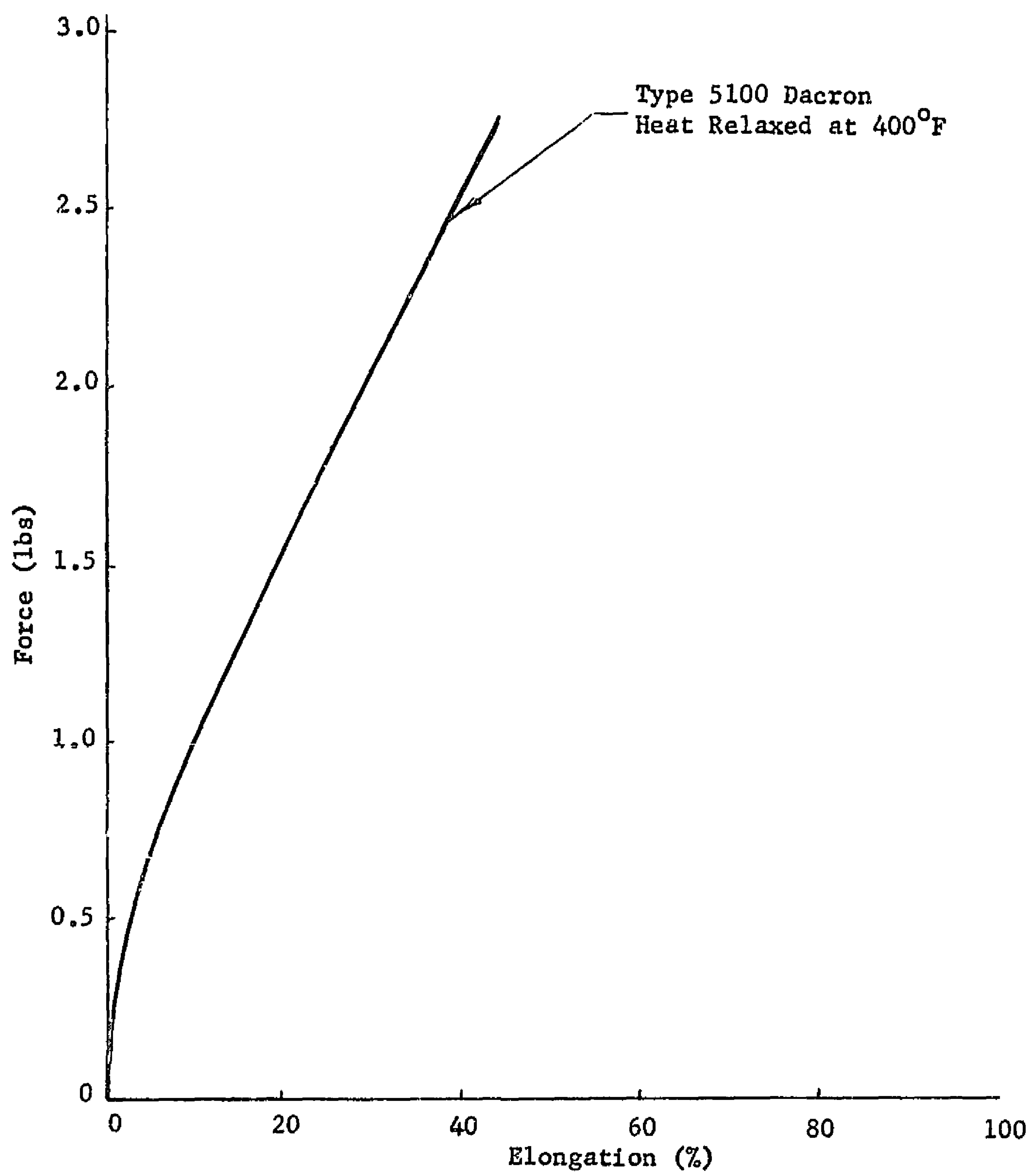


FIGURE 5

LOAD ELONGATION CURVE DACRON
YARN HEAT RELAXED
AT 400°F TESTED AT 30 FEET PER SECOND

4.0 APPLICATION OF YARNS TESTED

4.1 Discarded Yarns

The partially drawn N-13 nylon yarn produced extremely variable results and was dropped from further consideration. The heat-shrunk Dacrons did not exhibit the stress-strain curve shape with a flat post-yield slope which is required for energy absorption.

4.2 Formic Acid Treated Nylon Yarns

Type 300 nylon 55 yarns treated at 66° for 2 minutes in a 59% formic acid solution and nylon 6 were selected as the materials to be used in constructing two of the body support concepts evaluated.

Based on the test results of formic acid treated yarns this treatment technique was extended into woven material. Construction of these tapes required warp yarns to be of a nature that would react to the formic acid shrinkage and filling yarns to be relatively inert to the formic acid. In addition, the mechanical appearance of texture of these tapes had to be so designed to allow for shrinkage in the longitudinal direction. A relatively open design was utilized for this purpose.

4.2 (continued)

Stability of this tape during the treatment was achieved through the use of a balanced weave construction which was a 4 over 4 twill weave. In addition, the tape had a selvage woven using edge wires which produce a longer length of filling yarn resulting in reduced restraint during warp shrinkage. The ends of the treated tapes were sewn to a nylon tape conforming to MIL-T-5038, Type II which was made with a loop which would support the primary load. At a predetermined force, the loop would break open and transfer the load to the treated tape which would absorb energy by plastic deformation. The stress-strain characteristics of a tape assembly are shown in Figure 6.

The results of the subsequent body support assembly constructed from these tape assemblies are reported in Reference (1).

4.3 Application of Drawn and Undrawn Nylon Yarns

Undrawn nylon 6 yarns were assembled into a 3-ply cord construction and its characteristics were compared to the individual yarns as shown in Figure 7. These cords were fastened to the sides of the couch frame by a clamping arrangement with drawn nylon 300 yarns cemented to and perpendicular with the cords to add stability to the body

4.2 Formic Acid Treated Nylon Yarns - Cont.

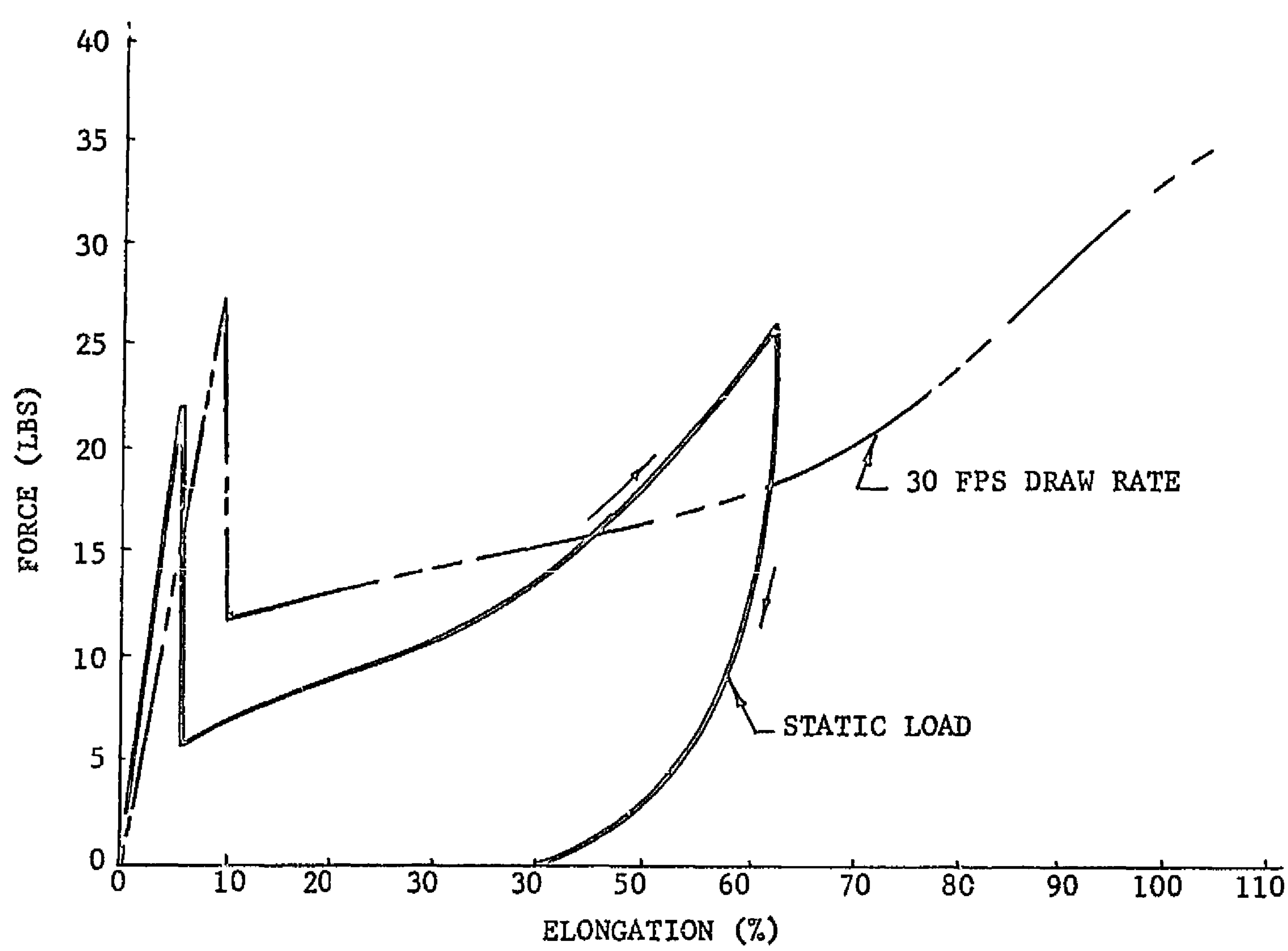


FIGURE 6

ELONGATION OF A LOAD
BEARING TAPE ASSEMBLY FORMIC
ACID TREATED NYLON

4.3 Application of Drawn and Undrawn Nylon Yarns - Cont.

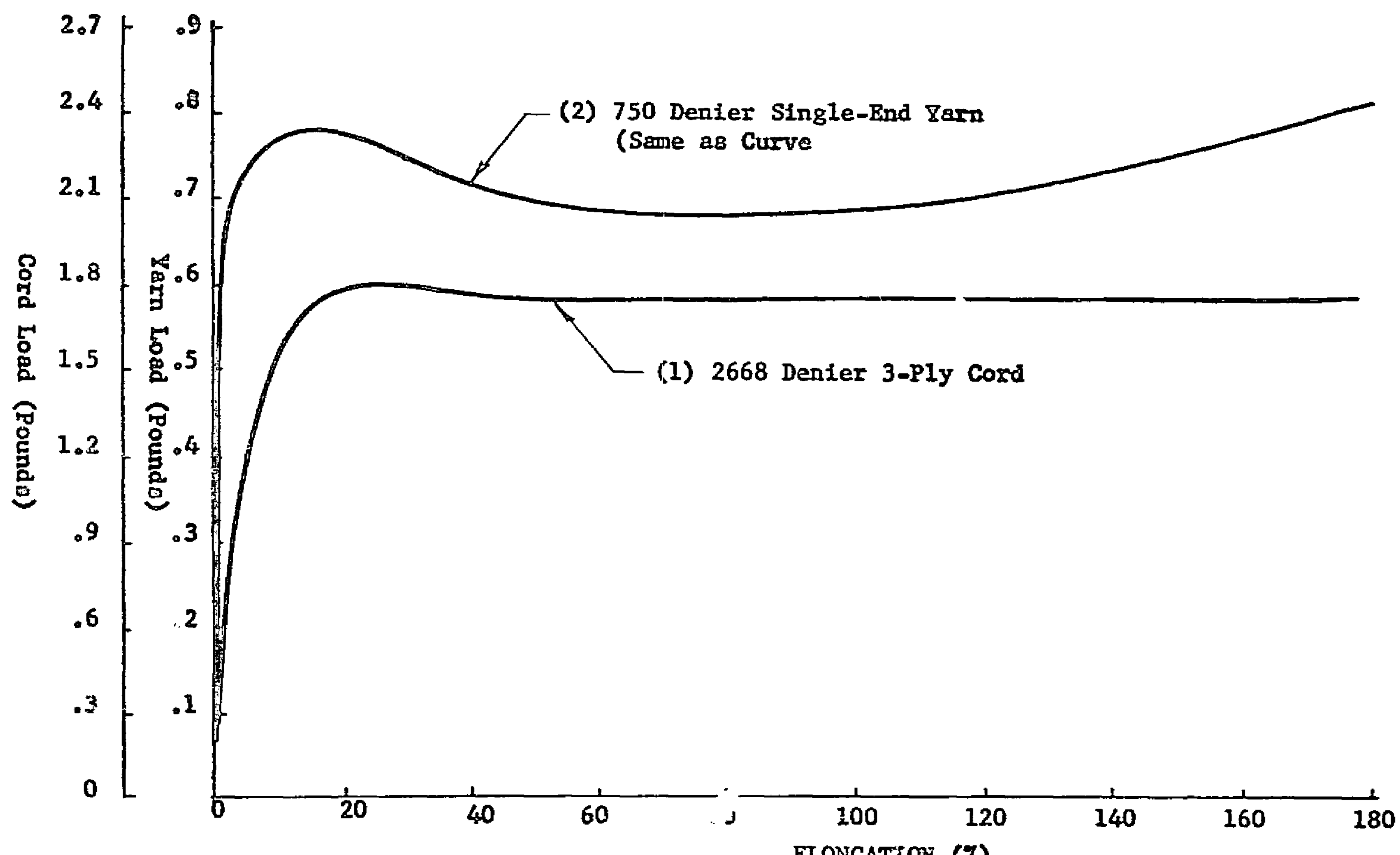


FIGURE 7

STRESS-STRAIN CHARACTERISTICS
OF UNTWISTED UNDRAWN YARN VS 3-PLY TWISTED CORD
MADE OF NYLON 6

4.3 (Continued)

support system. The results of a half scale model drop test is shown in Figure 8.

4.3 Application of Drawn and Undrawn Nylon Yarns - Cont.

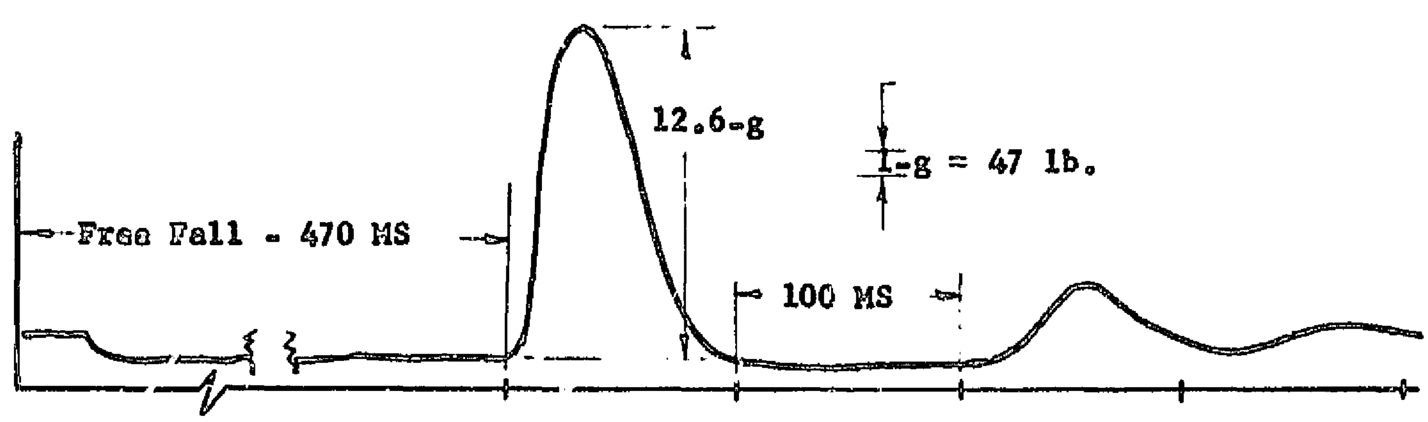


FIGURE 8

LOAD TRACE ON HALF-SCALE DROP TEST
FILAMENT WOUND CONCEPT

5.0 SYNTHETIC FIBER YARN TESTS

5.1 Development of Non-Curling Primary Support Attenuating Cord

A twisted 13/13 3 ply-750 denier undrawn Ny... yarn was used to fabricate support platforms. When slack, this cord had a strong tendency to curl making it difficult to install the platform on the supporting frame.

Three contructions were studied to obtain an attenuating cord with a low curling tendency as follows:

1. Braiding a cord from untwisted yarn
2. Balancing "single end" and "assembly" twists
3. Backing off on the assembly twist.

The results of twist stability test data for numerous cords is tabulated in Table 4.

TABLE 4

TWIST STABILITY OF UNDRAWN NYLON CORD

(3 PLY - 750 DENIER)

PROCESSED TWIST CONSTRUCTION	TWIST FREED TO UNWIND BUT NOT UNRAVEL
13/5.2	13/6.3
13/6.9	13/6.7 (repeatable)
13/7.6	13/8.6 (single trial only)
13/8.7	13/8.1
13/9.1	13/8.6
13/13	13/12

As indicated in Table 4, a twist of 13/6.9 appeared to have the most desirable properties.

A ply-twist of an initially 13.5/13.5 cord was mechanically backed off to develop an uncurling or "dead" cord. Characteristics of this construction are summarized in Table 5.

TABLE 5

TWIST STABILITY OF MECHANICALLY UNWOUND, UNDRAWN

NYLON CORD (13.5/13.5, 3 PLY-150 DENIER)

CONSTRUCTION OF UNWOUND CORD	TWIST FREED TO FURTHER UNWIND BUT NOT UNRAVEL
13.5/13.5 (not unwound)	13.5/12.5
13.5/12.5	13.5/12.5
13.5/11.5	13.5/11.7
13.5/11.0	13.5/11.3
13.5/10.0	13.5/11.0
13.5/ 8.0	13.5/10.2

Cords which mechanically unwound one to two turns per inch were considered "dead" and did not tend to unravel when cut. Elastic strain of these cords was reduced to a value approaching zero. Any additional strain resulting from the initial 13.5 turn ply-twisting operation was released by plastic flow or hysteretic loss.

The most promising cords of each construction were coated with 5 and 10 percent solid polyurethane cement solutions. Variations were obtained visually with an Instron testing machine and are summarized in Table 6.

TABLE 6

STRAIN RATE DATA (100 PERCENT/MINUTE) OF 750 DENIER, UNDRAWN NYLON CORD

CORD	SOLIDS POLY-URETHANE CEMENT COATING (PERCENT)	DRAW STRESS (POUNDS)*	BREAKING STRESS (POUNDS)**	ELONGATION AT BREAK (PERCENT)**
4-End Braided	None	2.10	7.40	508
	5	2.10	8.30	625
	10	2.10	8.77	572
3-Ply 13/6.9 Balance Twisted	None	1.50	5.80	575
	5	1.58	6.05	605
	10	1.61	6.88	656
3-Ply 13.5/12.0 Twisted and Strain Released	None	1.50	5.04	535
	5	1.50	5.36	533
	10	1.50	5.95	611

* Rubber faced jaws - initial separation 10 inches (average 2 tests)

** Rubber faced jaws - initial separation 2 inches (average 2 tests)

5.2 Properties of Non-Curling Primary Support Attenuating Cord

A typical stress-strain curve for 3-ply attenuating cord with the effect of temperature and humidity variation on draw stress characteristics is shown in Figure 9.

The requirement for the couch to support a static load of 16 ± 2-g's necessitated short term creep testing of selected attenuating cord. Results of these tests are tabulated in Table 7.

5.2 Properties of Non-Curling Primary Support Attenuating Cord - Cont.

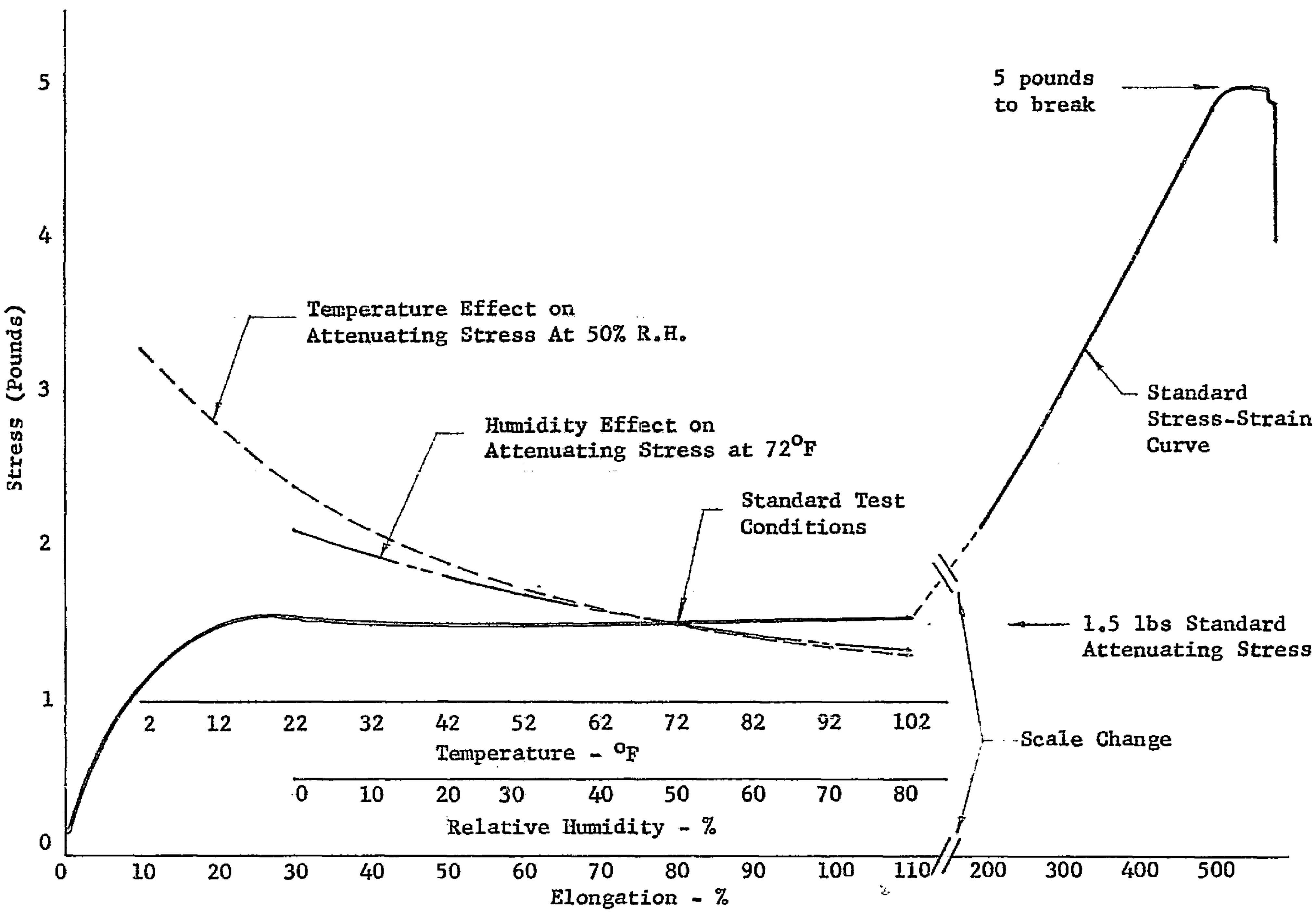


FIGURE 9

PHYSICAL CHARACTERISTICS OF 3 PLY-840 DENIER NYLON ATTENUATING CORD

5.2 Properties of Non-Curling Primary Support Attenuating Cord - Cont.

TABLE 7

SHORT TERM CREEP RELAXATION PROPERTIES[1] DATA

(750 DENIER UNDRAWN NYLON 6 YARN WITH 3/4-POUND DRAW STRESS)

LOADING CONDITION	ACCUMULATED TIME (MINUTES)	DRAW STRESS LOADING PERCENTAGES				
		80%	70%	60%	50%	40%
High-Load Creep Elongation	0	0	0	0	0	0
	1	18.8	6.9	3.9	3.4	2.6
	2	22.4	8.0	4.6	3.6	2.8
	3	25.1	8.7	5.2	3.8	2.9
	4	25.8	9.5	5.5	3.9	3.0
	5	27.0	9.9	6.0	4.0	3.1
Reduced Load[2] Elongation Decay	5[3]	17.0	5.4	3.0	2.4	2.5
	6	15.7	3.6	2.2	2.4	2.2
	7	15.3	3.2	2.0	1.9	2.1
	8	14.8	3.1	1.8	1.8	2.0
	9	14.7	2.9	1.7	1.8	2.0
	10	14.5	2.8	1.7	1.8	2.0
	15	13.6	2.6	1.6	1.7	1.9

(1) Expressed as percent elongation on original sample length

(2) Weight reduced to tare or 9.5 percent of yarn draw stress

(3) Read only seconds after creep attenuation reading was made and and load removed.

The results in Table 7 demonstrate that creep for short increments is inconsequential when the attenuating cord is subjected to static loading equal to or less than 60 percent of inherent draw stress.

5.3 Properties of Secondary Lacing Cord

Three cords were considered for use as secondary support lacing and were tested for physical properties on the Instron tester. Data from these tests is tabulated in Table 8.

TABLE 8

PROPERTIES OF SECONDARY LACING CORDS
(STRAIN RATE 100 PERCENT/MINUTE*)

CORD	LOAD TO BREAK (POUNDS)	ELONGATION AT BREAK (PERCENTAGE)
2 Ply-840 Denier 13/13 Twisted Dacron	29.2	30.0
2 Ply-840 Denier 13/13 Twisted Nylon	26.9	37.8
4 Ply-840 Denier Braided, Nylon	31.2 (erratic)	30.6

* 10-inch sample, rubber-faced jaws.

The Dacron cord (type 68 - formerly D420, DuPont Company), a high-strength polyester fiber, was selected as the secondary lacing cord because of slight strength advantage and a higher cord modulus.

The breaking strength and percent of selected Dacron lacing cords under varying conditions of temperature and humidity are tabulated in Table 9.

5.3 Properties of Secondary Lacing Cord - Cont.

TABLE 9

PHYSICAL PROPERTIES 2-PLY DACRON LACING CORD
(STRAIN RATE 500 PERCENT/MINUTE*)

TEMPERATURE (DEGREES F)	RELATIVE HUMIDITY (PERCENT)	LOAD TO BREAK (POUNDS	ELONGATION AT BREAK (PERCENT)
72	50	28.8	28
72	0	29.2	29
72	33	28.1	28
72	76	22.1	27.5
72	90	22.8	27
110	50**	25	23.5
32	50**	24.1	18
0	50**	25.5	17

* 2-inch sample, rubber-faced jaws.

** Stabilized in testing room at 72°F and 50 percent relative humidity, then conditioned in temperature controlled chamber for 1 minute prior to testing.

5.4 Secondary Lacing Tests

The Apollo couch platform is designed to attenuate high impact loads to 20 $\pm$ 2-g's. Undrawn nylon cord has been developed to perform this function. The platform must also withstand a 16-g load, however, without attenuating. To assist in this task a secondary lacing is superimposed on the primary cord structure which must break out to permit load attenuation when required.

Recent drop tests disclosed the existence of a spike in the attenuated curve that reached 31.8-g's and was traceable to the secondary lacing structure. Tests were laid out to investigate the possibilities of eliminating this spike in further platform designs. A 12" lacing suitable for a typical body torso section was selected for the test program which consisted of both low speed load application and high speed impact (drop) tests.

Drop tests were the first to be conducted. The drop weight was 88-1/2 lbs. The test sample consisted of a primary attenuating support and superimposed, various secondary lacing supports. Lacing cords used are described in Table 10.

5.4 Secondary Lacing Tests - Cont.

TABLE 10

LACING CORD CHARACTERISTICS

Specimen No.	Material	Construction	Twist	Treatment	Strength Lbs to Break	Strength Gr/Denier	% Elong. @ Break
1	Dacron Type 52	2/1100	13/13	None	32.75	6.74	18.0
2	Dacron Type 52	2/1100	13/13	Estane Coated	32.75	6.74	19.5
3	Dacron Type 52	2/1100	13/13	Covered with Braided Nylon	33.375	6.97	20.0
4	Dacron Type 68	2/840	13/13	None	29.55	7.97	16.25
5	Dacron Type 52	4/1100	13/13	Estane Coated	50.00	5.05	
6	Nylon Type 714	2/840	13/13	None	30.5	8.23	27.25
7	Nylon Type 6	1/1260	1/0	None	25.0	9.0	18.75
8	Rayon High Tenacity	1/2200	1/0	None	21.87	4.51	9.25
9	Rayon Low Tenacity	6/900	13/13	None	19.7*	2.02	20.5*
10	PVA (Vinal)	2/1200	13/13	None	35.87	6.76	14.87

* Based on test of single untwisted 900 denier yarn.

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5.4 Secondary Lacing Tests - Cont.

The primary attenuating cords calculated for the weight and cross section of the simulating torso section resulted in:

51 ends/inch based on a draw stress of 1.5 lbs.

36 ends/inch based on a draw stress of 2.1 lbs.

32 ends/inch based on a draw stress of 2.4 lbs.

Thirty-six cords per inch were used for two drop tests. Thirty-two however, more nearly produced the attenuating characteristics desired and were used for the remainder of the tests conducted.

Calculations of the secondary lacing, predicated on using a double lay up of cord #4 above and an effective breaking strength of 18 lbs. (in accordance with the practice followed prior to the current test series) established a grommet spacing of .857". This facilitates 28 single cord crossovers in a 12" section or 56 assuming the doubled lacing. The design strength of 18 lbs. is only 61% of the cords' normal tensile strength.

Because tests to be reported later suggested that the elongation at break of a lacing or the secondary support structure is greater than originally anticipated, a revised input became available and new calculations of the secondary lacing for the test section were made. These disclosed that

5.4 Secondary Lacing Tests - Cont.

a lacing only 82% as strong as originally calculated will best satisfy the design specifications.

Results of the drop tests actually conducted are summarized in Table 11. A grommet spacing established by the first described calculations was incorporated into the samples tested.

For each test made, the drop weight was first placed on the primary windings. Under the 1-g loading, the secondary lacings were snugged up and fastened. High speed load tracings are shown in Figures 10 through 23.

Next - pull tests were made on a full scale, 12" wide, secondary support section which duplicated the corresponding elements of the drop test samples. The results of these are summarized in Table 12.

It is apparent that the single saw-tooth lacing is superior to the other lacing configurations. Considering this type only, a 61% lacing efficiency as was previously assumed does not appear to be out of line.

5.4 Secondary Lacing Tests - Cont.

TABLE 11

BODY SUPPORT SECTION DROP TESTS

Drop Test No.	No. of Primary Cords	Lacing Cord Material	No. of Lacing Cross-overs	Theoretical[1] Lacing Strength -lbs	Percentage of Initial Calculated Requirement	Percentage of Revised Calculated Requirement	Recorded g's Input	Recorded g's Spike	Recorded g's Plateau
1 [2]	36	None (Control)	-	-	-	-	48	16	11
2	36	Dacron Type 68	41	57.3	73.2	91.8	40	25[3]	21
3	32	Vinal PVA	38	64.5	82.4	103.3	41	21.5[3]	19.5
4	32	Dacron Type 68	46	64.3	82.1	103.0	40	20	19
5	32	H. Ten. Rayon	62	64.2	82.0	102.8	41	27	19.5
6	32	Nylon Type 6[4]	54	63.9	81.6	102.2	43	25	19
7	32	Dacron Type 52[5]	41	63.6	81.3	101.8	44	22.8[3]	19
8	[illegible]	Dacron Type	41	63.6	81.3	101.8	44	20.7[3]	18
	[illegible]	Low Ten. Rayon	68	63.6	81.3	101.8	42	27	19
		Dacron Type 52[6]	40	63.1	80.7	101.1	42	22.8	19
[illegible]		None (Control)	-	-			46	21.4	18.5
12	[illegible]	Dacron Type 52	44	68.1	87.0	109.0	44	28	20
13	32	Dacron Type 52	54	83.6	81.3	134.0	43	25.5	20
14	32	Nylon Type 714	44	63.4	80.9	101.4	44	23.5	20.5

1. Assumes 61% strength efficiency in laced configuration.
2. Data questionable.
3. Delayed spike.
4. High tenacity.
5. Estane coated.
6. Undrawn nylon braided cover.
7. Rubber lined grommets

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5.4 Secondary Lacing Tests - Cont.

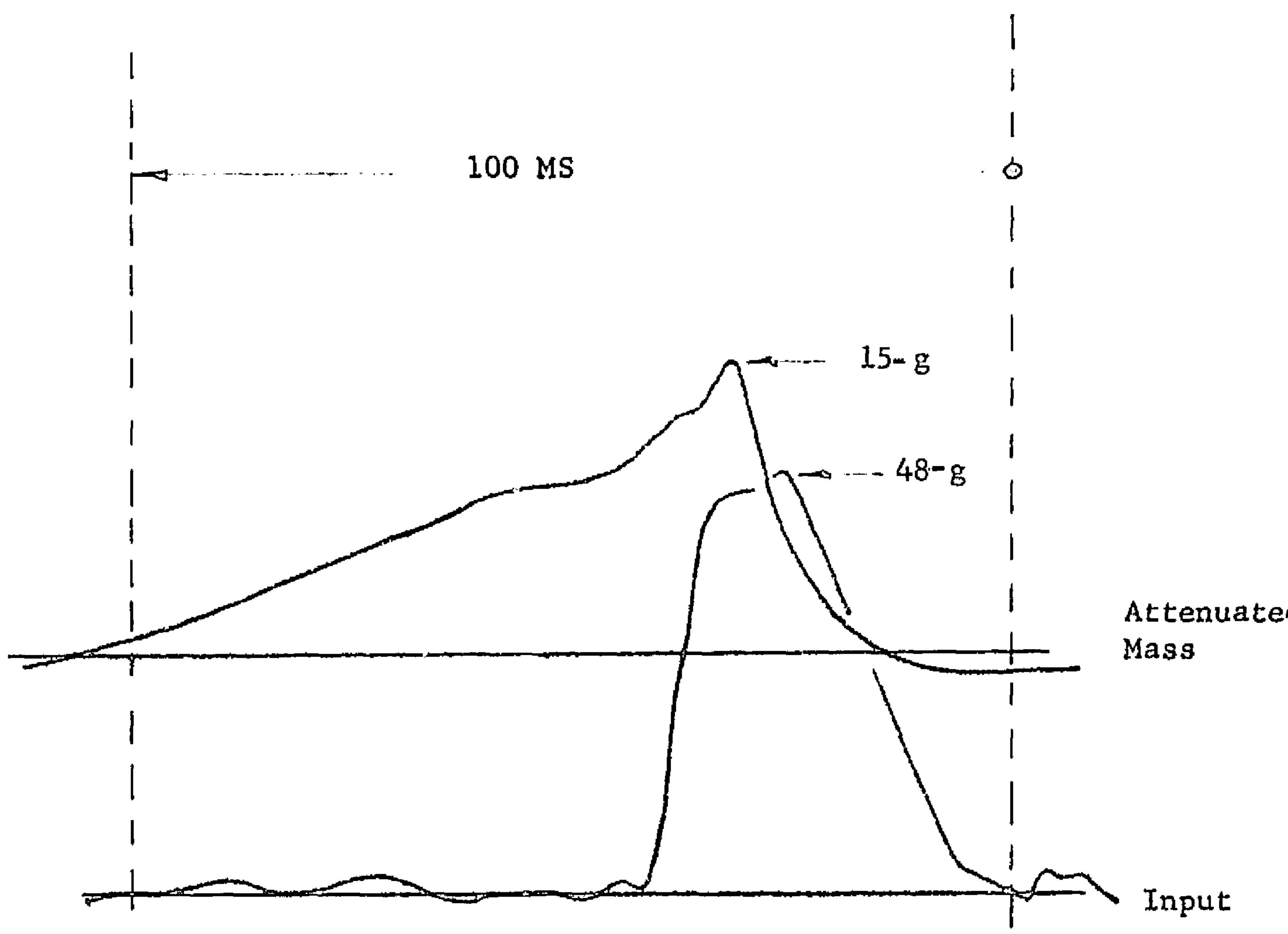

FIGURE 10

DROP TEST 1 - NO LACING CORD
36 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

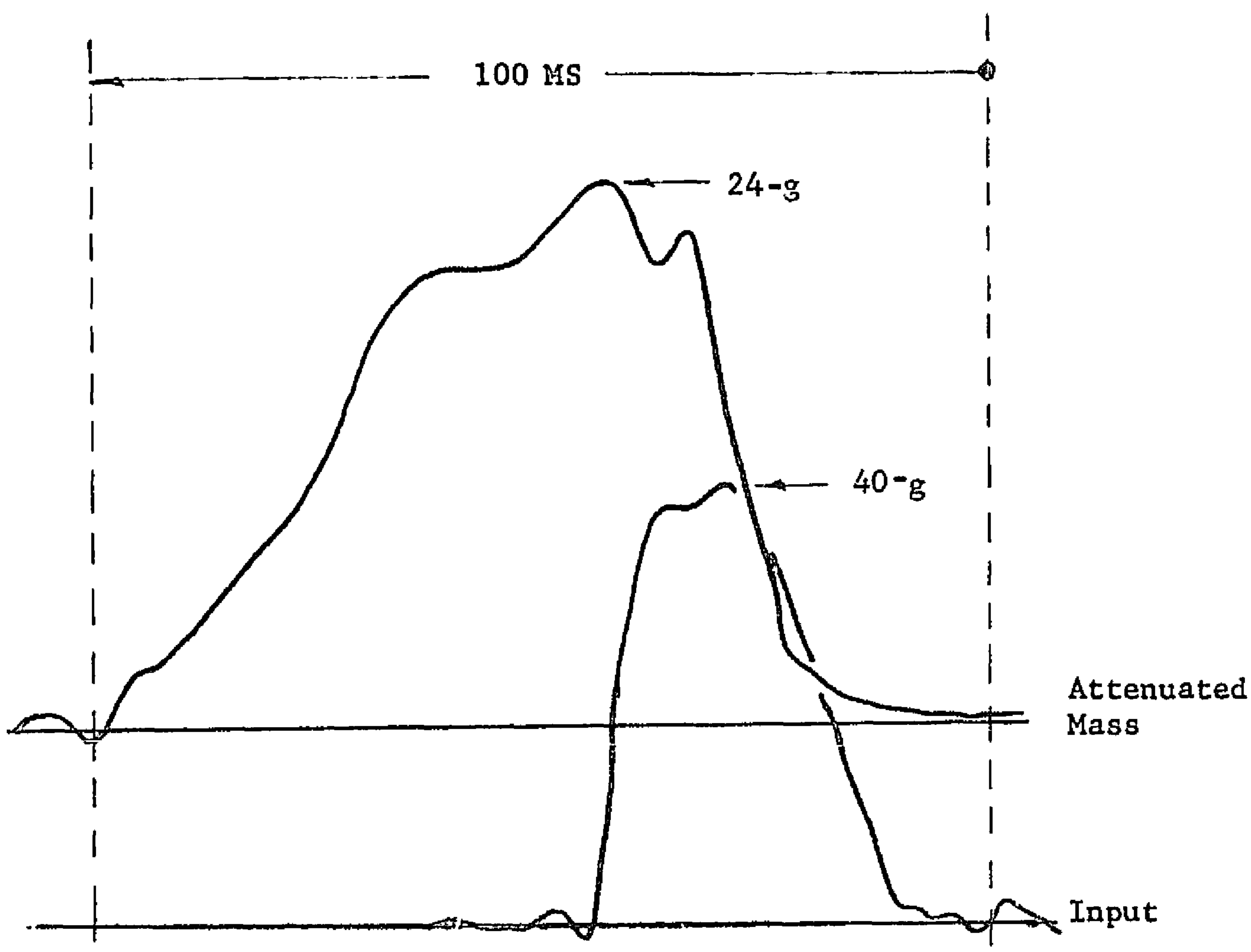

FIGURE 11

DROP TEST 2 - DACRON TYPE 68 LACING CORD
36 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

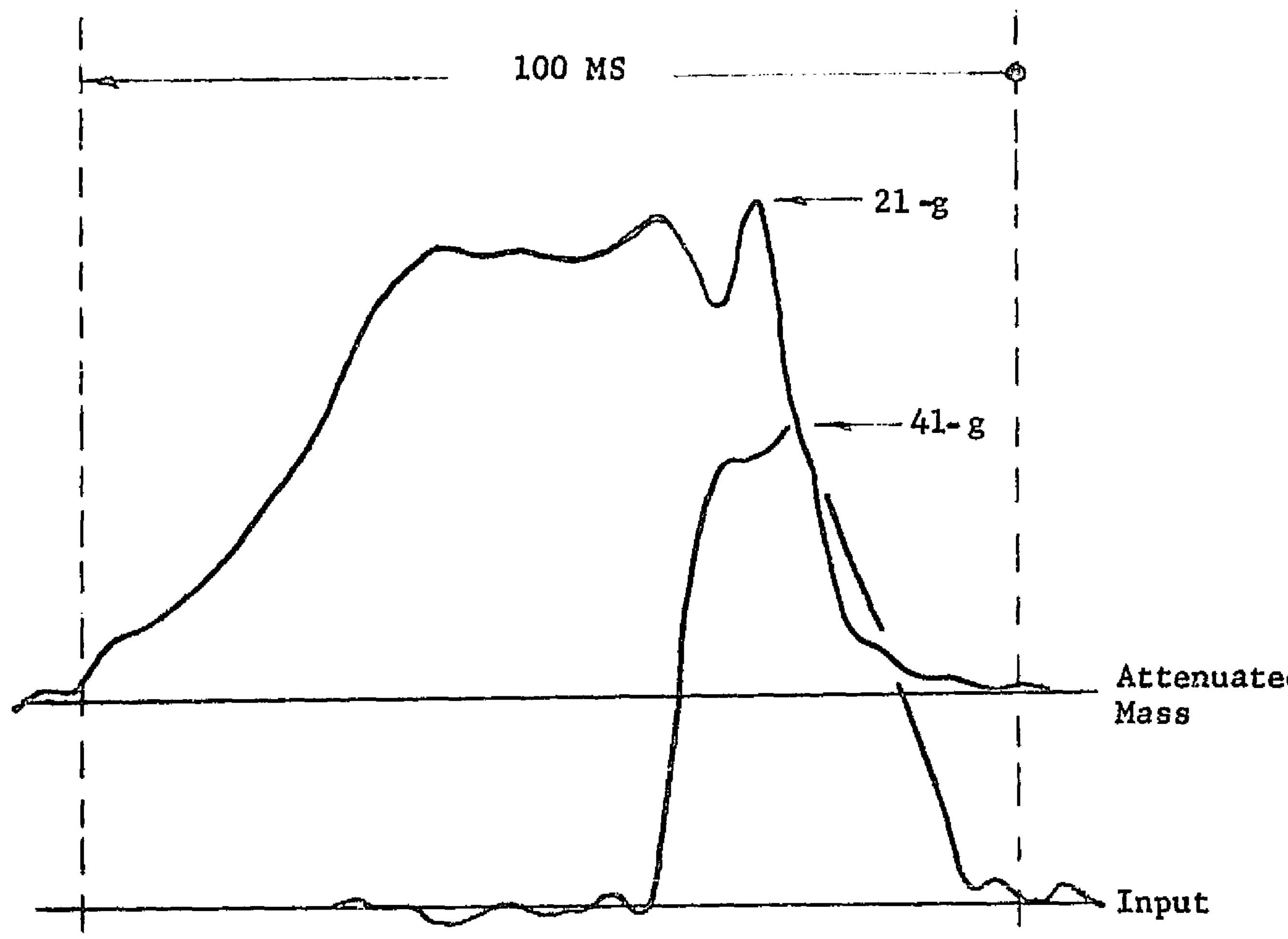

FIGURE 12

DROP TEST 3 - VINAL PVA LACING CORD
32 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

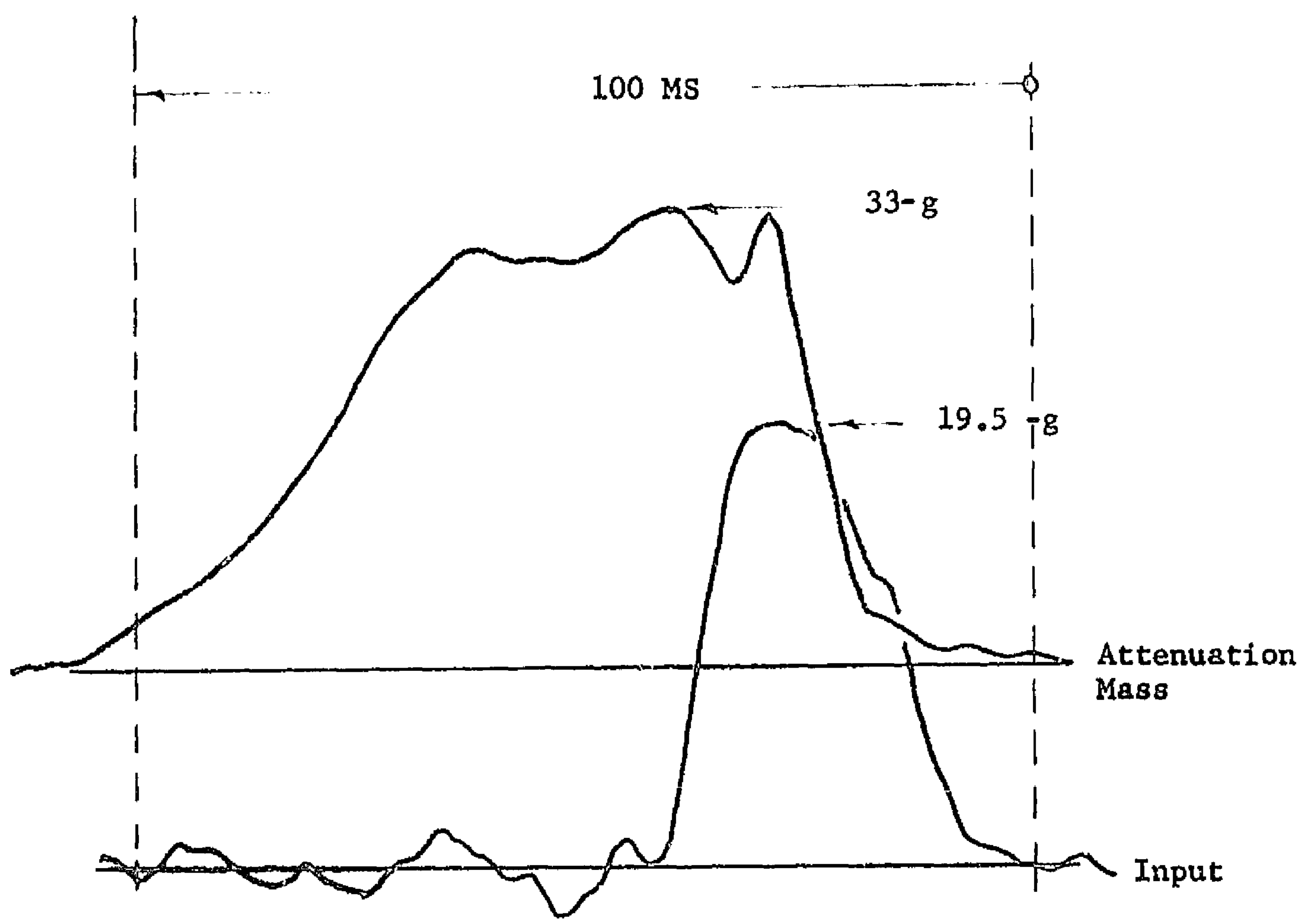

FIGURE 13

DROP TEST 4 - DACRON TYPE 68 LACING CORD
32 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

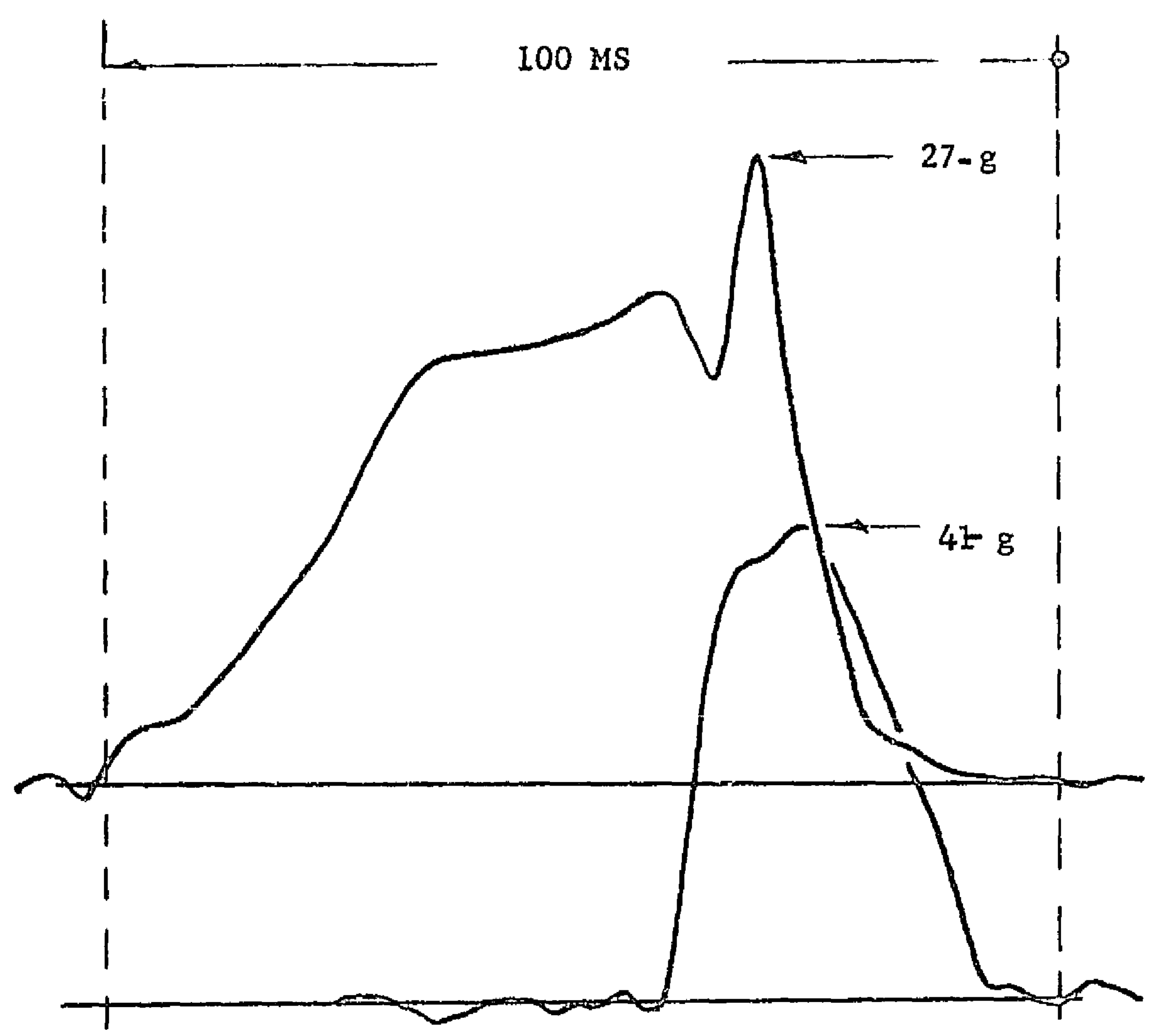

FIGURE 14

DROP TEST 5 - HIGH TENCITY RAYON LACING CORD
32 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

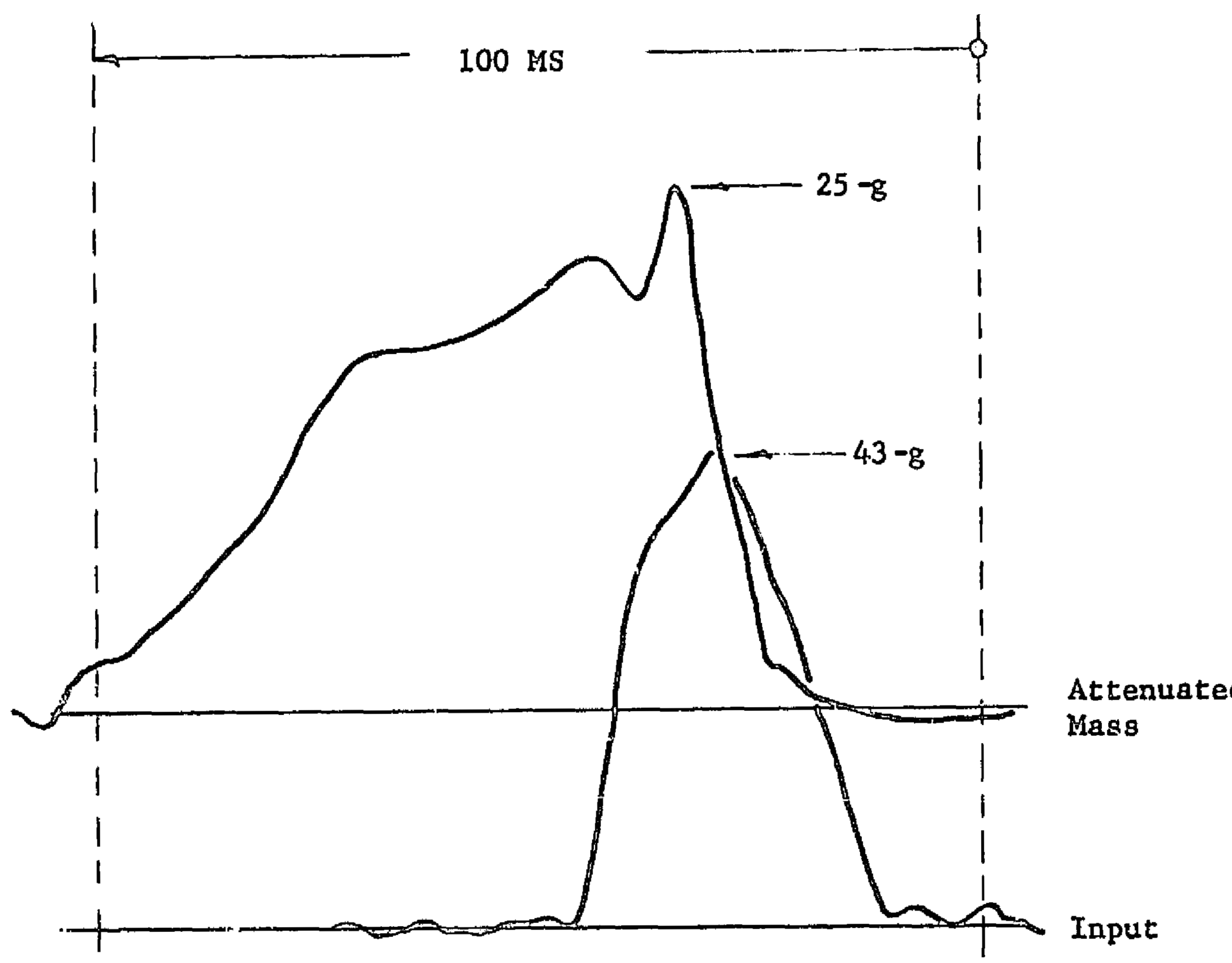

FIGURE 15

DROP TEST 6 - NYLON TYPE 6 LACING CORD
32 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

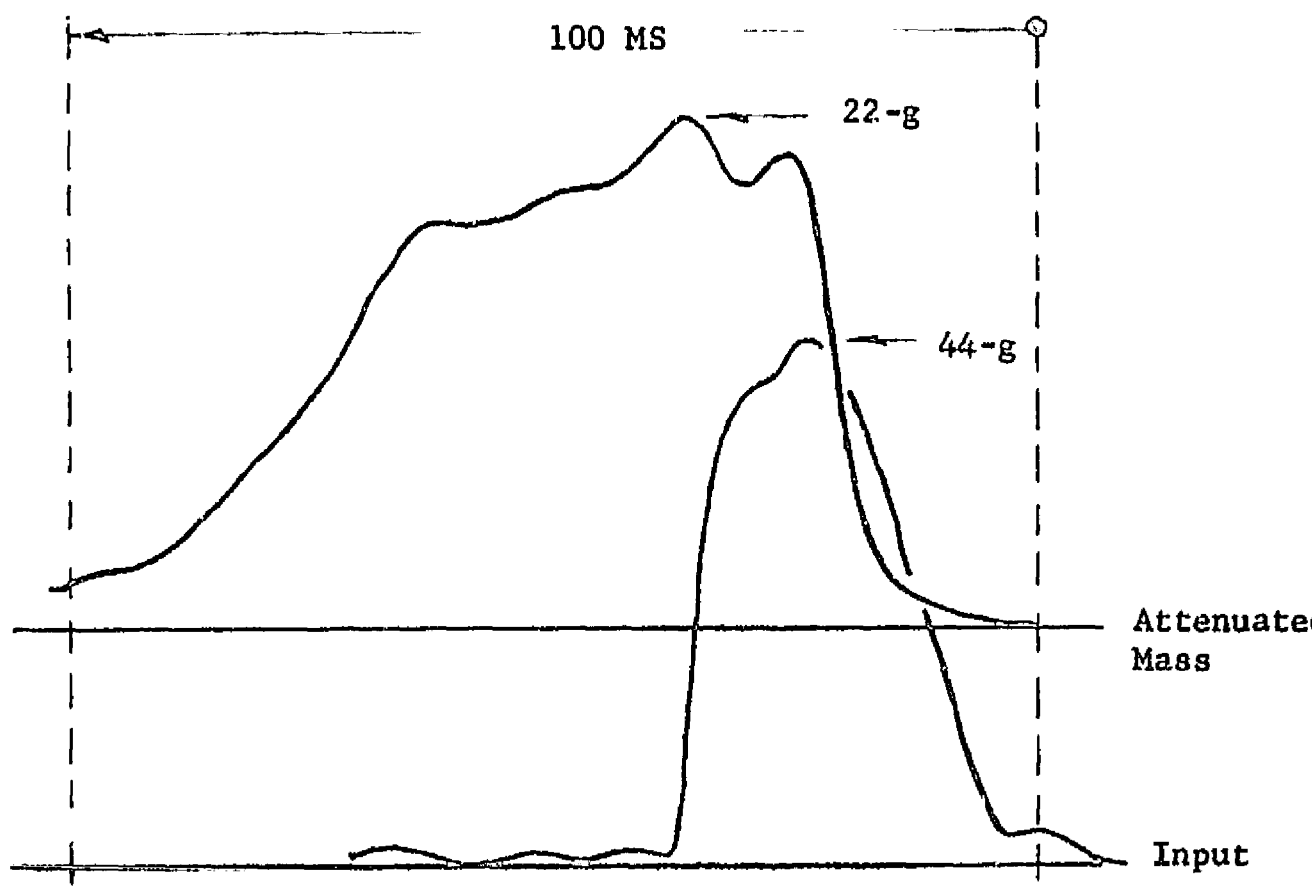

FIGURE 16

DROP TEST 7 - DACRON TYPE 52 LACING CORD
32 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

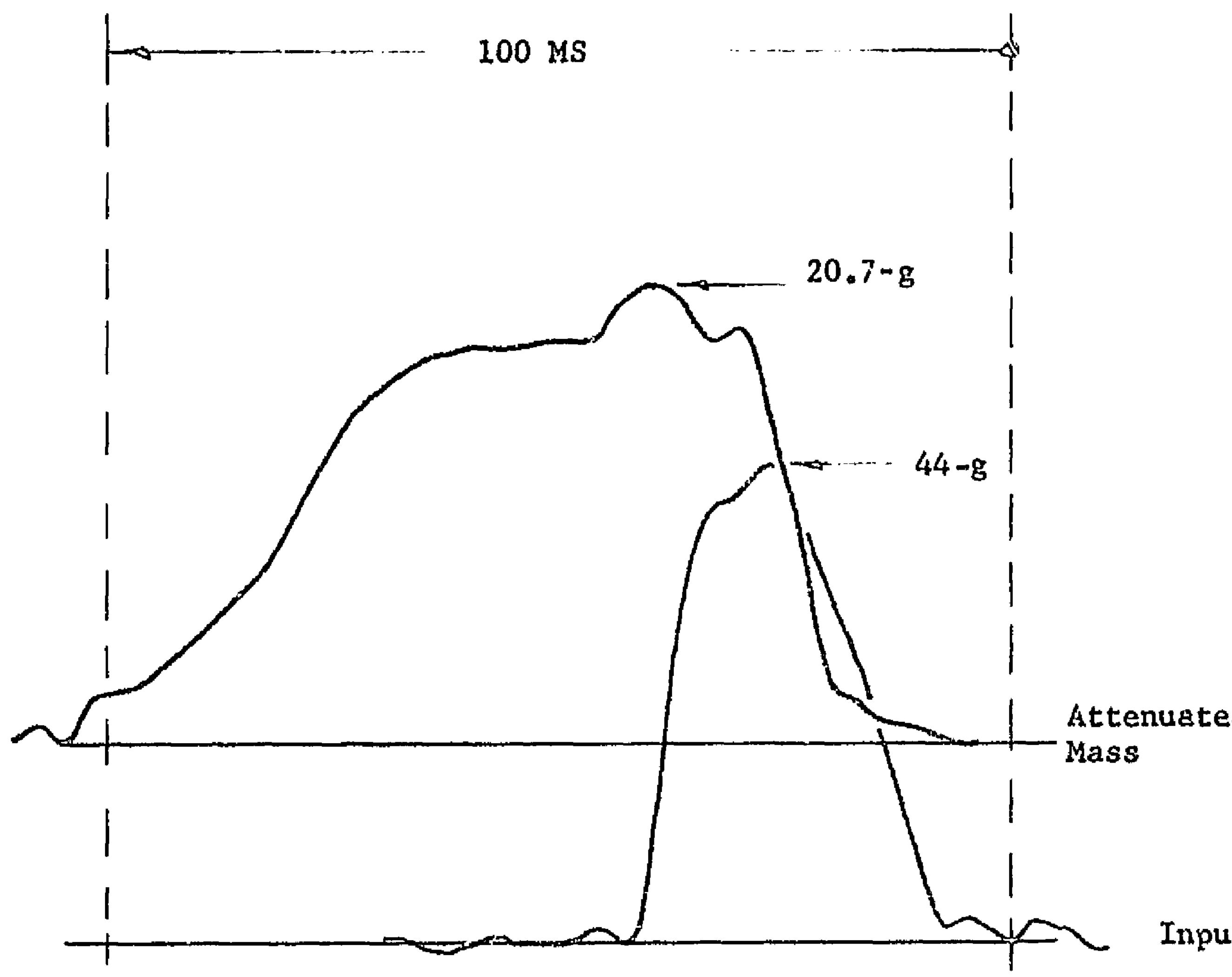

FIGURE 17

DROP TEST 8 - DACRON TYPE 52 LACING CORD
32 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

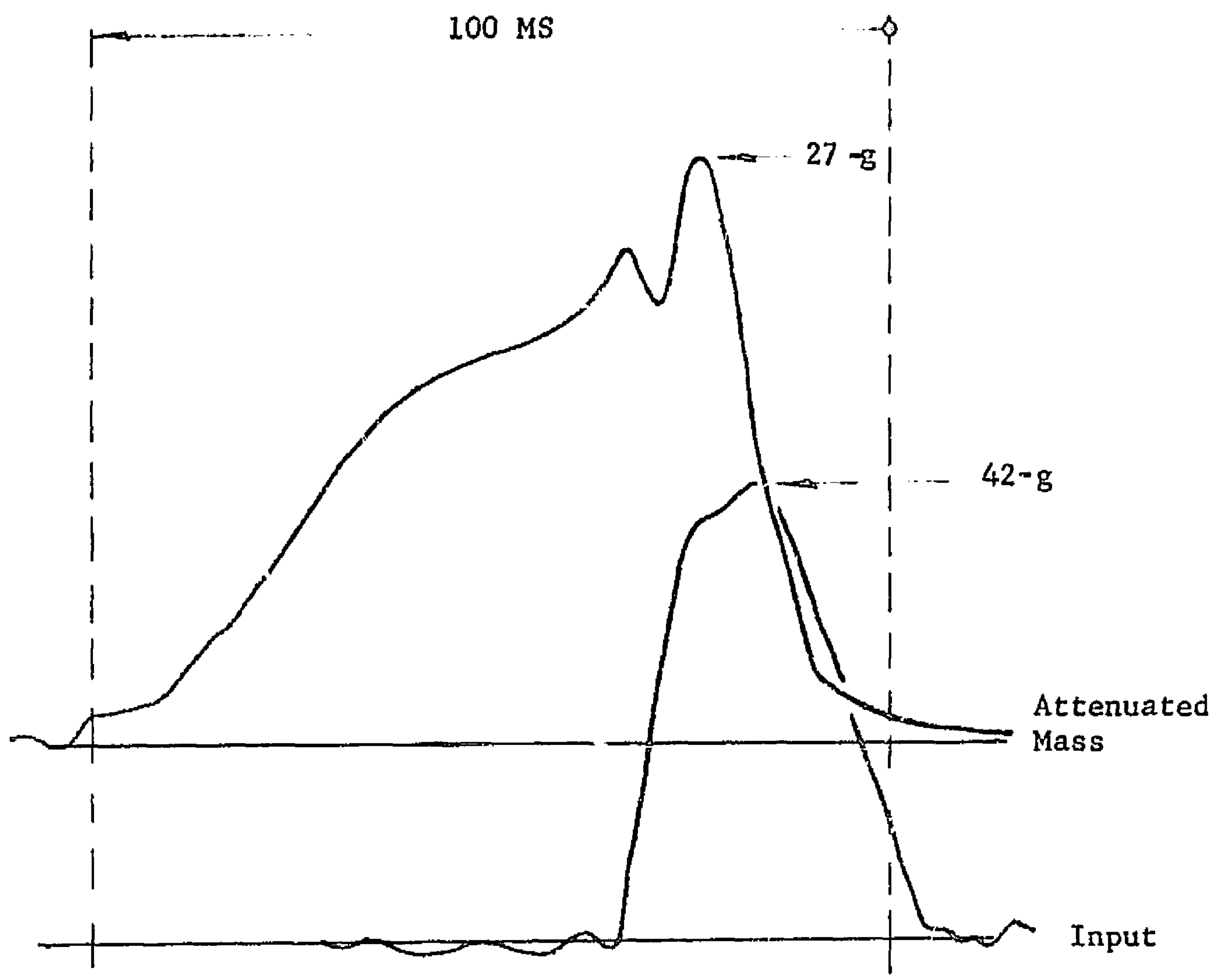

FIGURE 18

DROP TEST 9 - LOW TENACITY RAYON LACING CORD
32 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

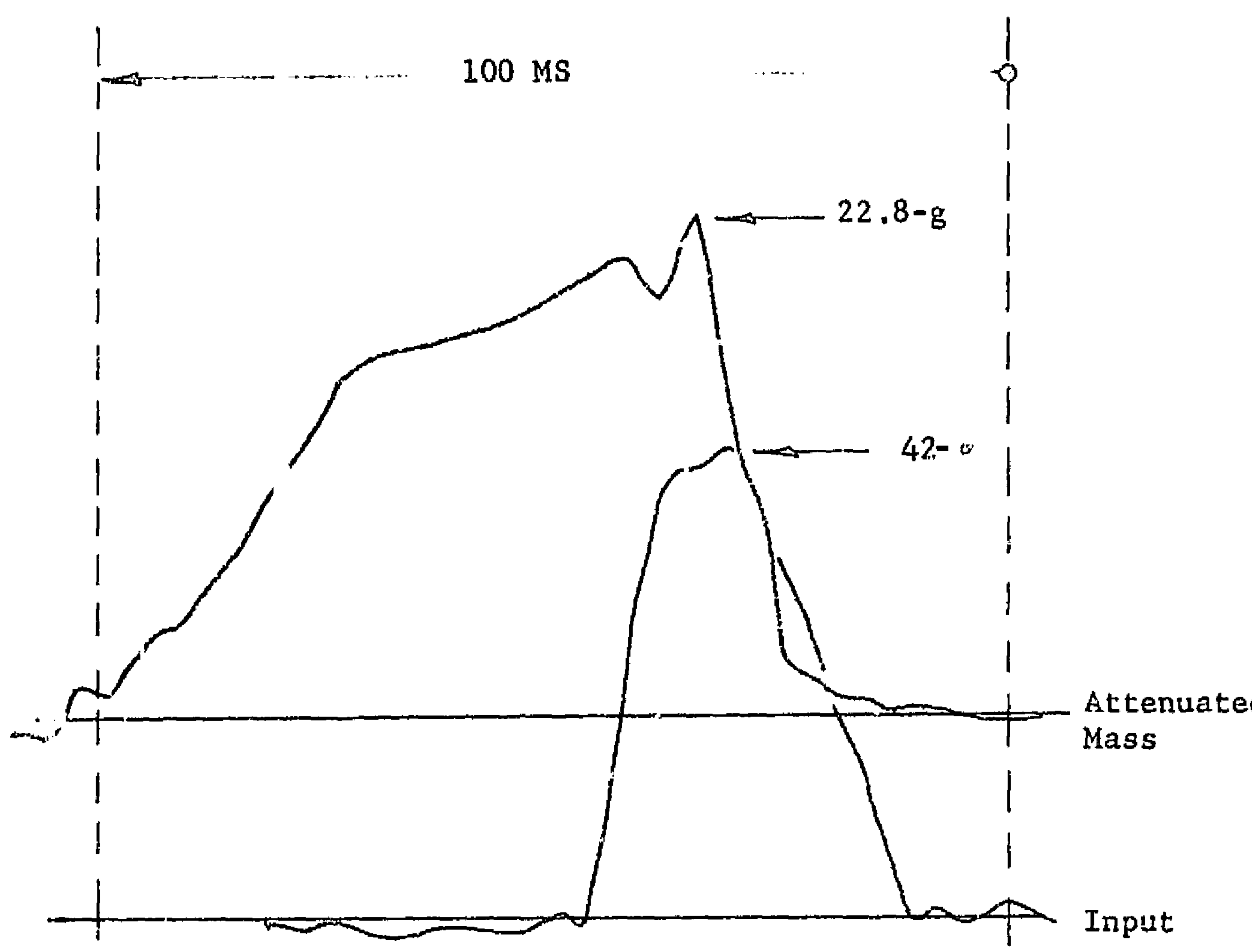

FIGURE 19

DROP TEST 10 - DACRON TYPE 52
LACING CORD
32 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

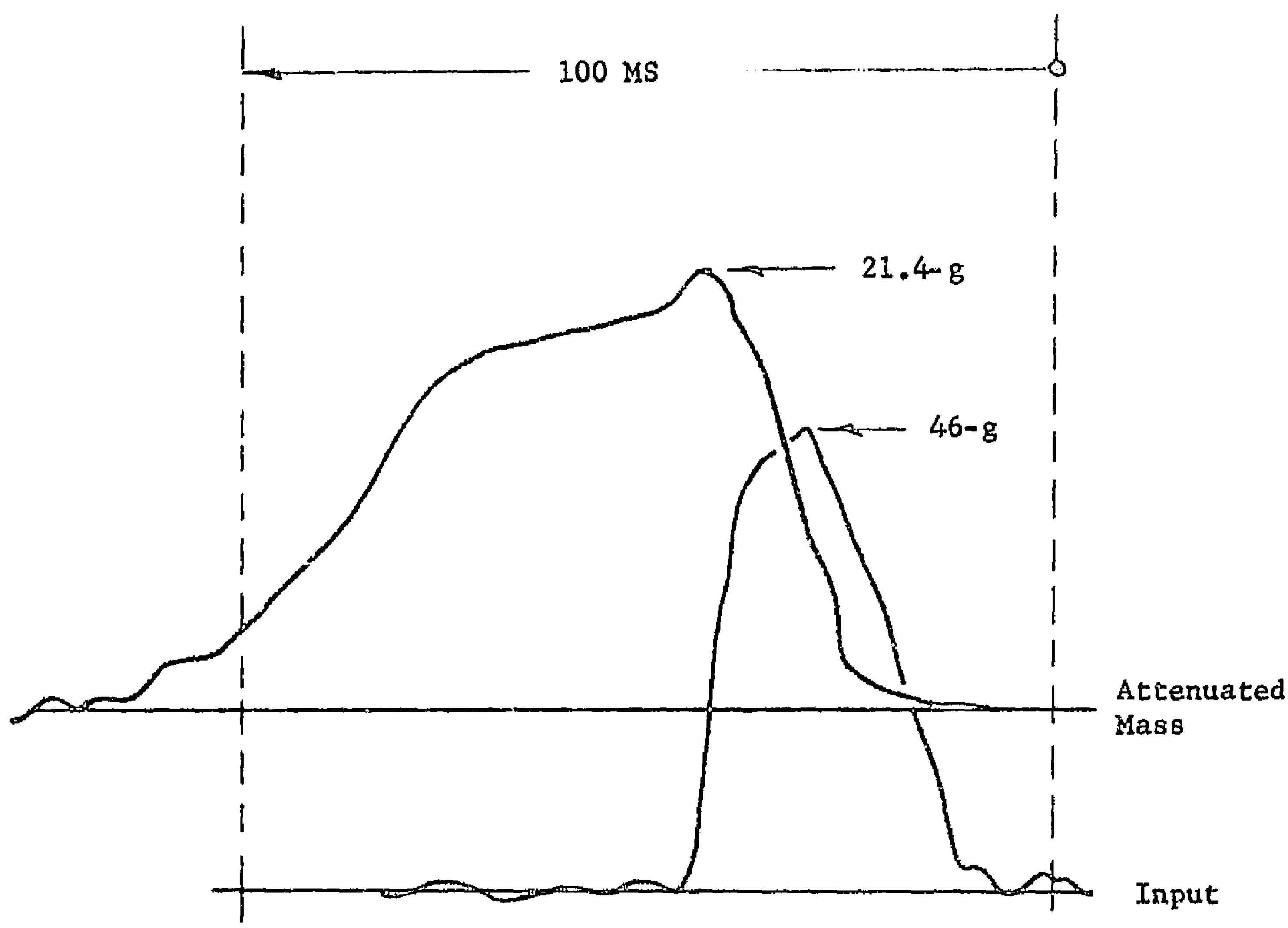

FIGURE 20

DROP TEST 11 - NO LACING CORD
32 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

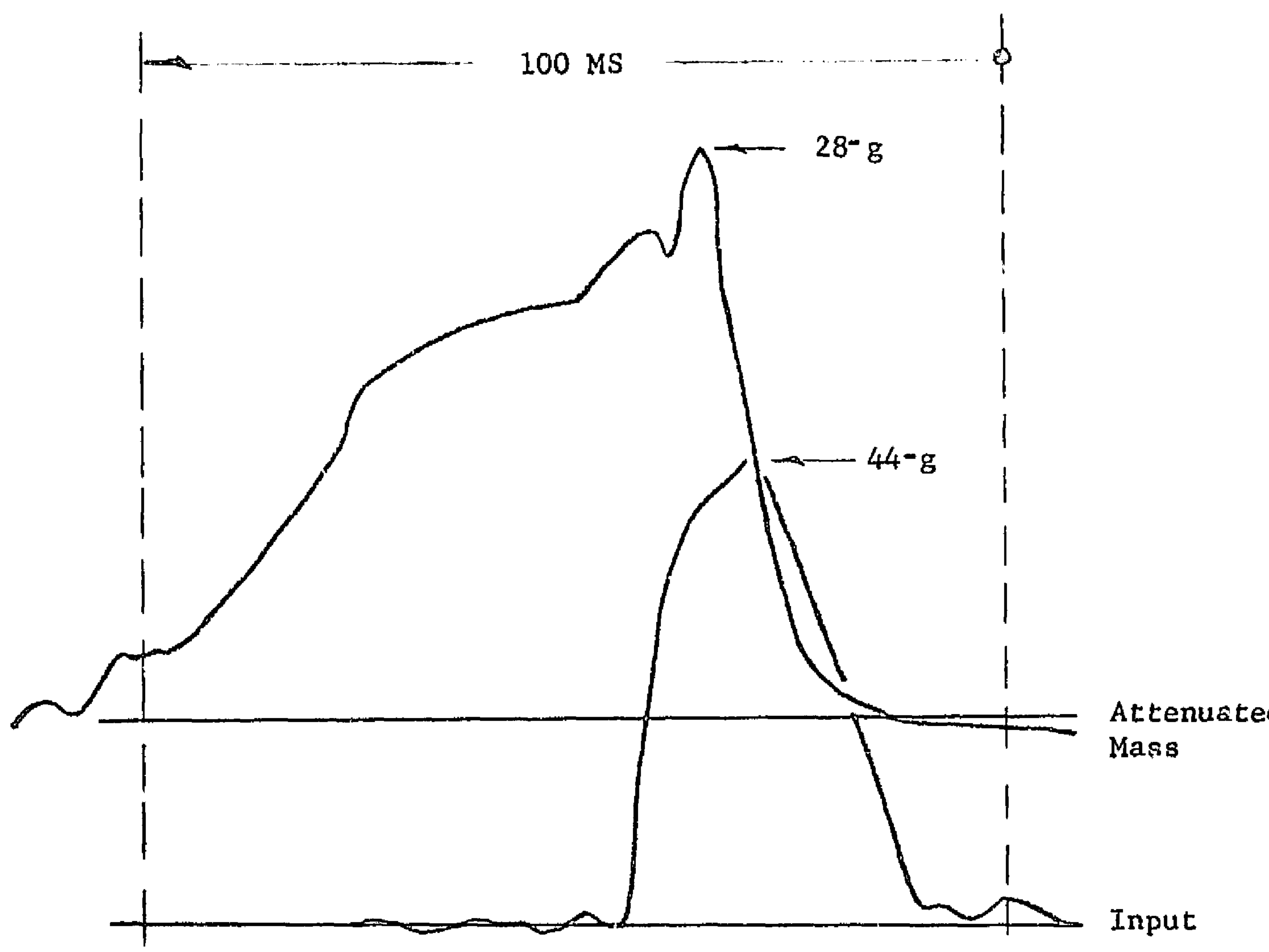

FIGURE 21

DROP TEST 12 - DACRON TYPE 52 LACING CORD
32 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

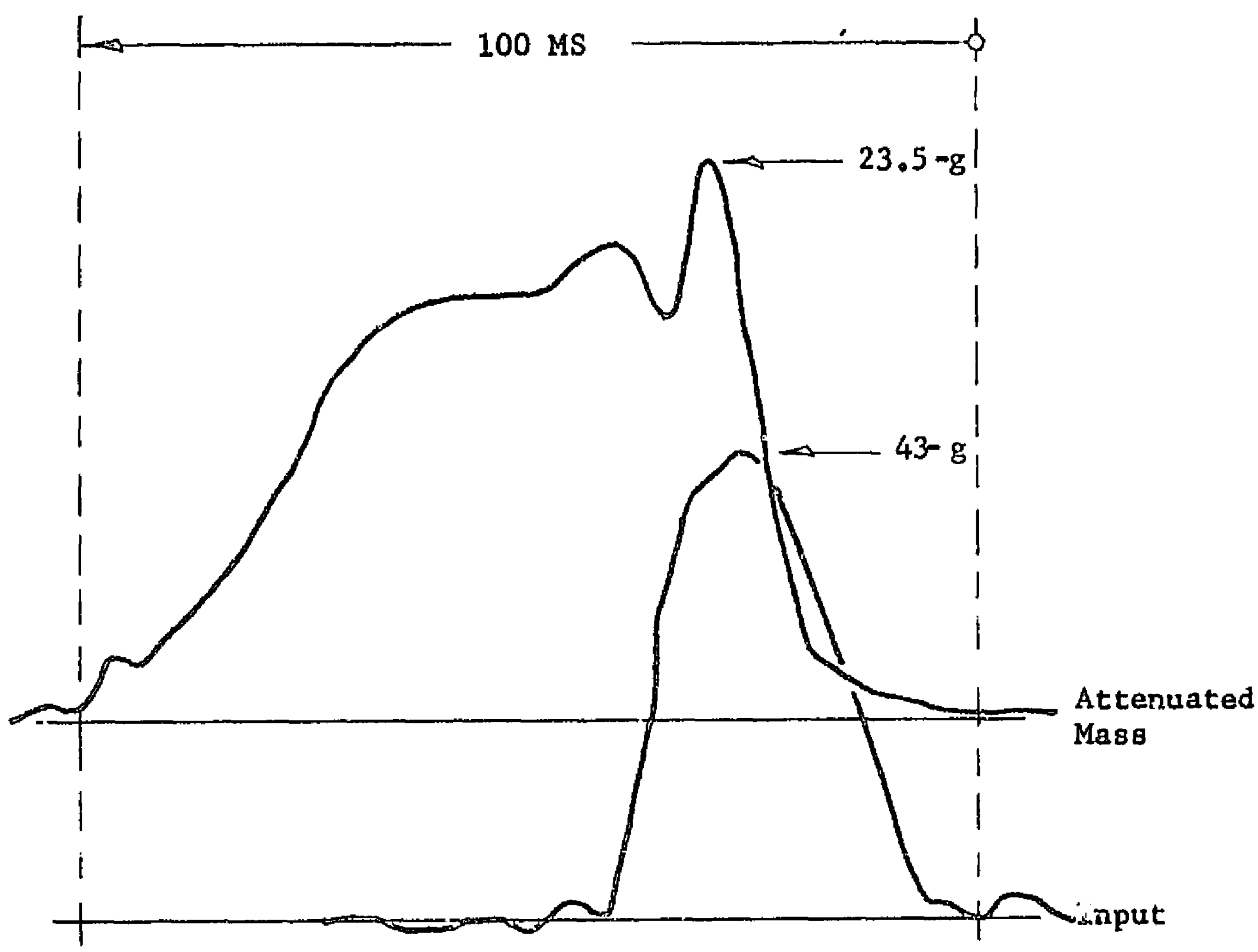

FIGURE 22

DROP TEST 13 - DACRON TYPE 52 LACING CORD
32 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

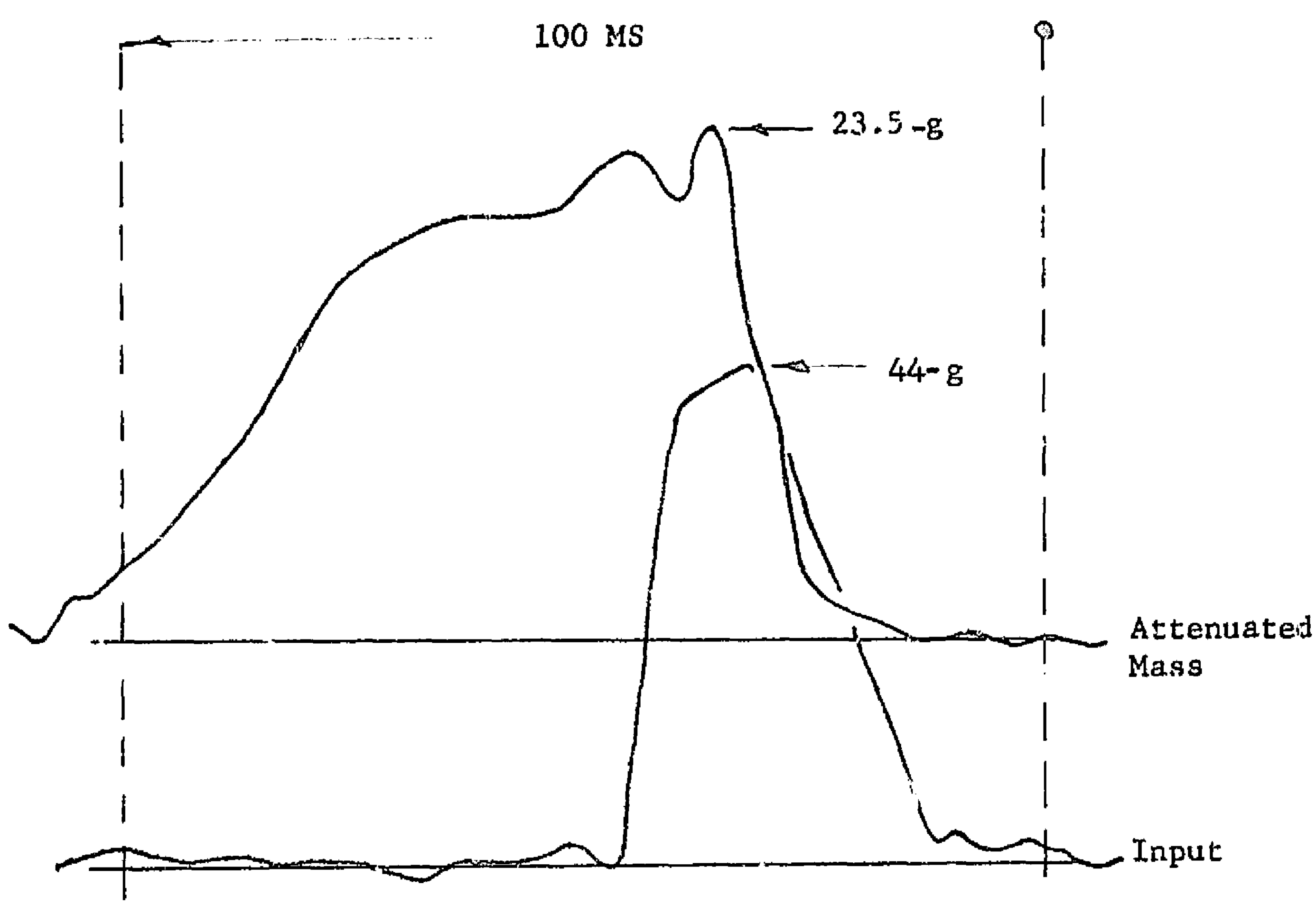

FIGURE 23

DROP TEST 14 - NYLON TYPE 714 LACING CORD
32 PRIMARY CORDS

5.4 Secondary Lacing Tests - Cont.

TABLE 12

SECONDARY LACING STATIC LOAD TESTS 12" SECTION

Test No.	Lacing Cord Material	No. of Lacing Cross-overs	Theoretical[10] Lacing Strength -lbs.	Test Breaking Load -lbs.	Elongation @ Break (inches)	Actual[16] Lacing Efficiency -%
1	Dacron Type 52	41[3]	63.6	620 [11]	2.7	49.6
2	"	41[3]	63.6	580 [12]	1.8	46.3
3	" [1]	41[3]	64.8	605 [13]		47.5
4	" [1]	41[3]	64.8	655 [14]	1.9	51.4
5	"	54[4]	83.7	760	2.2	46.1
6	"	28[5]	43.4	500	1.5	57.7
7	"	32[6]	49.6	435	2.1	44.5
8	"	41[7]	63.6	600	1.8	48.0
9	"	28[8]	43.4	460	1.5	53.9
10	"	28[9]	43.4	590[15]	1.7	68.1
11	" [2]	28[5]	66.2	840[11]	2.6	64.4
12	" [2]	28[5]	66.2	840[12]	2.4	64.4
13	" [2]	28[5]	66.2	900[12]	2.4	69.0

1. Braided cover of undrawn nylon.
2. Estane coated.
3. Lacing doubled and criss-cross in center of sample, single lacing on sides.
4. Lacing doubled and cross-crossed over nearly full sample width.
5. Single sawtooth lacing.
6. 16 doubled and parallel crossovers near center of sample width only.
7. Lacing doubled and parallel near edges of sample, single lace in center.
8. Straight cross over lacing.
9. Standard saw tooth lacing one end, straight cross-over lacing other end.
10. Assumes 61% strength efficiency in laced configuration.
11. Upper lacing broke.
12. Upper lacing replaced and broke again.
13. Bottom lacing broke.
14. Bottom lacing replaced and broke again.
15. Straight lacing broke out.
16. Based on strength of individual cord.

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5.4 Secondary Lacing Tests - Cont.

The drop tests support the conclusion that a secondary support designed by assuming a 61% lacing efficiency along with the revised estimate for lacing elongation, should not, when suitably adjusted relative to the primary support, result in an objectionable spike in the attenuated impact load experienced.

6.0 MATERIALS SELECTION

The 13.5/13.5 nylon cord (which was unwound by hand to 13.5/12.0) was selected as most nearly satisfying the requirements of the program. This nylon cord and the 13/13 twisted Dacron lacing were incorporated into Body Support Assembly (Weber Drawing SK 10344). When mounted to the Apollo Couch Assembly (Weber Drawing SK 10343), these cords provide sufficient body member support for the couch occupant under several simulated Apollo launch, re-entry, and landing load conditions.

7.0 LIST OF MATERIALS

Outlined below is a list of all the materials and their finishes which were utilized in the fabrication of the couch system.

a. Aluminum Alloys:

All aluminum alloys conformed to one of the following specifications:

Extrusions	QQ-A-200
Rolled, Drawn and Cold Finished Bars	QQ-A-225
Sheet and Plate	QQ-A-250

b. Carbon Steel Alloys

Carbon steel were utilized in the form of bolts, nuts, and restraint fittings only. Materials conforming to applicable Government Specifications were used.

c. Corrosion Resistant Steel Alloys

The following alloys were used:

Bar	QQ-S-763	Class 303 and 304
Wire	QQ-W-423	Comp FS 302

7.0 Continued

d. Nylon Cords and Yarns

The body support was fabricated from the following nylon cords and yarns:

Type 6 Undrawn Nylon Yarns
Type 700 Nylon Yarns
Type 711 Nylon Yarns
Type 69 Nylon Thread

e. Nylon Fabrics

The following fabrics and webbing were utilized in the construction of the body support and restraint:

Style S/SN 270R - Fabric, Mfg. Wellington Sears
Pattern 7282 Code 2921 - Tape Mfg. Bally Ribbon Mills
MIL-W-4088D Webbing

f. Miscellaneous Materials

Type 101 Nylon Rod
Teflon 1200
Type 55 Royalite
Type AL Ensolite
"Vyrene" Polyurethane Elastic Thread
Polyurethane Foam Cover Backing
Type 5740-101 Estane Resin - Adhesive
Type 2216-3M-Adhesive

7.0 Continued

g. Finishes and Surface Treatments

Aluminum alloys were anodized per MIL-A-8625 Type 1.

Corrosion Resistant alloys were passivated per MIL-S-5002.

Lubrication was accomplished with Everlube 620 solid dry film lubricant and Dow Corning DC-4 Silicon Grease.

Appearance finish of couch structure was No. 3615 Dark Gray (FED-SPEC TT-C-595) XA-194 Spacecraft Coating Mfg'd by Andrew Brown Co., Irving, Texas.

The body support cover material was dyed with a anthraquinone Sky Blue Dye.

REFERENCES

1. Weber Report DR 5893, "Phase I & II Final Report on the Development of a Uni-Directional Lightweight Energy Absorbing Net Couch-Restraint System for Use in the Apollo or Follow-On Projects" - D. Johansen, 19 August 1966.

END